1985 NASA AUTHORIZATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

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1985 NASA AUTHORIZATION

WEDNESDAY, FEBRUARY 1, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 1:04 p.m., in room 2318, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Present: Representatives Volkmer, Brown, Mineta, MacKay, Nelson, Fuqua (ex-officio), Lujan, Lowery, Chandler, Bateman, and Walker.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

This afternoon the subcommittee begins our review of the NASA fiscal year 1985 budget request.

We want to welcome once again NASA Administrator James Beggs and the Deputy Administrator, Dr. Hans Mark, and Mr. Newman.

Jim, I want to congratulate you personally on gaining approval of a forward-looking program. The space station initiative is important not only to the agency but also to our Nation and will enable the United States to continue to exert world leadership in the space arena. Although the space station has received by far the most public attention, the other new initiatives—the upper atmospheric research satellite mission and the Mars geoscience/climatology orbiter—are equally important.

As we embark on the space station activity, we must assure that adequate resources are devoted to building a healthy science and applications base with which we can exploit such a capability. Many have suggested that the life science and materials processing programs stand the most to gain from a permanent manned facility; yet these budgets remain relatively unchanged in the 1985 budget request.

NASA's management and stewardship of the space station program must improve over recent experience to avoid the cost and schedule problems which have become fairly commonplace.

There are also budget concerns. I am very concerned that while there is almost total agreement that we will need a fifth orbiter, NASA is still watching the costs increase and the production line disappear. Gentlemen, such budget gamesmanship is poor stewardship and is not in the public interest. I have little doubt that

within the next 2 years we will see a request for a fifth orbiter but at a significantly increased cost.

In another area, the subcommittee plans to carefully review the redirection of the advanced communications technology satellite program. The flip-flop and start-stop episodes in this area waste not only public resources but those of the private sector as well.

As the subcommittee reviews the budget request, we will carefully examine the balance between space transportation activities and space science and applications activities. We will also continue to exercise vigilance over the relationship between NASA space activities and those of the national security establishment.

Again, Jim, I would like to congratulate you on a very good budget. We look forward to working with you and completing our review of the budget in the next several weeks.

I would also like to announce that our ranking minority member will also have a statement, and that statement will be made a part of the record at this point.

[The opening statement of Mr. Lujan follows:]

OPENING STATEMENT OF HON. MANUEL LUJAN, JR.

Thank you, Mr. Chairman. Welcome, Mr. Beggs. I have seen a preview of the NASA budget request for FY 1985 and I am delighted with the strong support this administration continues to give the space program.

I believe we are well aware of how the space program has driven the technology development for new industries—the examples are numerous and varied. I believe we are also well aware of how the future space program can continue to provide new scientific understanding and continue to drive the technology development necessary to maintain U.S. economic strength.

The FY85 budget request shows clearly that you, the Administration, and, of course, the President understand and agree with this view. I am especially excited to see there are three new initiatives in the NASA budget. The Space Station clearly has received the most attention, and indications are that it has already caught the public's imagination.

But there are two other new initiatives which should be noted—the Mars Orbiter and the Upper Atmospheric Research Satellite. These three initiatives all reflect the Administration's policy of supporting basic research and technology development while forming a strong partnership with industry and the universities.

In view of the strong and growing enthusiasm among the private sector about the commercial possibilities in space, you will have several coming challenges. The traditional NASA challenges of technology development and extending the frontier of our capabilities will continue. But another challenge will be working out the partnership with other nations eager to join us in developing the potential of space—and with our own U.S. industry eager to make space an important part of our national economy. NASA has always had an activist approach—of making things happen. But sometimes government involvement precludes entrepreneurial activities. Industry involvement takes two forms—that of the NASA contractors who have historically been NASA's partners in space—and that of the entrepreneur who will have a crucial role in space commercialization. How NASA will handle the government's role in making space commercialization possible is a key issue to be resolved.

I look forward to hearing your testimony about NASA's plans for the next year and to discussing these issues with you. It looks like an excellent budget proposal.

Thank you, Mr. Chairman.

Mr. VOLKMER. We also will have a statement from the chairman of the full committee, Mr. Fuqua, and that statement will be made a part of the record at this point.

[The opening statement of Mr. Fuqua follows:]

OPENING STATEMENT OF HON. DON FUQUA

Jim, I too, would like to congratulate you on a very good budget. I am delighted with the NASA budget request because it not only represents real growth but also advocates a strong balanced commitment to current efforts and presents a bright future for the agency.

I believe the Committee and our colleagues in the House will support the space station effort. Both the Committee and the House have always supported the Space Program in a bipartisan manner.

I would commend the Administrator not only for the Space Station initiative, but also for the commitment to gain both private sector and international participation.

A very real opportunity exists to gain increased economic benefits from our space research and development investments through financial participation by the private sector. Furthermore, the space station program offers an opportunity for international cooperation in a peaceful endeavor.

I share the concerns expressed by the Subcommittee Chairman with regard to the Fifth Orbiter and the Advanced Communications Technology Satellite program. I can assure you that we are going to look closely at how we can fit the fifth orbiter into the budget.

Again, congratulations on your overall budget including the space station and the two new science and applications initiatives.

Mr. VOLKMER. Just before we proceed, I ask unanimous consent that media and communication equipment be allowed for the purpose of recording this hearing. Hearing no objection, we will proceed.

Mr. Beggs.

STATEMENT OF HON. JAMES M. BEGGS, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY DR. HANS MARK, DEPUTY ADMINISTRATOR, AND THOMAS NEWMAN, COMPTROLLER

Mr. BEGGS. Thank you, Mr. Chairman.

It is particularly a pleasure to appear before this subcommittee this year to present President Reagan's budget request for NASA for fiscal year 1985. Total agency requests are $7.5 billion, of which $2.4 billion is for research and development, including $342.4 million for aeronautics research and technology; $3.6 billion for space flight, control, and data communications; $160 million for construction of facilities; and $1.3 billion for research and program management. A chart summarizing NASA's fiscal year 1985 budget request is appended to my statement. You will recognize, Mr. Chairman, that the categories are those which reflect the change in structure of the NASA budget from last year.

In his state of the Union message to Congress last week, President Reagan outlined a bold new initiative for the United States which will maintain and insure, during the decade of the 1990's and beyond, our hard-won position of leadership in space. The President's initiative is a permanently manned space station to be in operation within a decade. It is a fundamental element of his vision for this Nation's future.

The space station will: reflect and contribute to America's commitment to research, technology and productivity; be a peaceful, visible demonstration of U.S. strength and commitment to leadership; implement the clear direction the civil space program has needed and found in the President's national space policy set forth in July 1982.

The time for space station is ripe. The agenda for tasks which can be undertaken and enhanced using the unique capabilities of

the space station is full. Both U.S. industry and the NASA institution are fully prepared to implement the President's initiative. The station is, as I have stated many times, the next logical step in space.

The idea of a space station, Mr. Chairman, is not new; however, a combination of circumstances makes the President's initiative especially timely. The most important reason to begin a space station now is that the space shuttle is approaching fully operational status. After a 10-year development program, we now have the capability to reach low-Earth orbit routinely. To maximize the unique advantages provided by the environment of space, we need to establish a permanent presence that enables us to work in space full time and fully utilizes the capabilities of the space shuttle. Without the capability of the shuttle, it would be impossible to establish the more permanent presence in space referenced by the President on July 4, 1982, in his National space policy statement. A second reason is that the operations we have conducted with the shuttle have stimulated great interest in the private sector to look toward investments in future space activities. The construction of a space station is necessary to create the facilities that will greatly encourage such investment and to stimulate new technology that will spin off into the U.S. economy. Finally, the shuttle has also stimulated great international interest in the U.S. space program, as evidenced by the overwhelming reception of the *Enterprise* in Europe last summer and the recent highly successful flight of the spacelab. As the President stated, we will plan the space station program in such a way that it will be possible for our friends and allies around the world to participate with us in taking this major step.

Based upon NASA and industry analyses over the past 18 months, the space station program will serve a number of functions, among which are: A laboratory in space for the conduct of science and the development of new technologies; a permanent observatory to look down upon the Earth and out at the universe; a transportation node where payloads and vehicles are stationed, processed, and propelled to their destination; a servicing facility where these payloads and vehicles are maintained and, if necessary, repaired; an assembly facility where, due to ample time on orbit and the presence of appropriate equipment, large structures are put together and checked out; a manufacturing facility where human intelliqence and the servicing capability of the station combine to enhance commercial opportunities in space; a storage depot where payloads and parts are kept on orbit for subsequent deployment; and, finally, a staging base for more ambitious future missions.

Perhaps more important than any of these individual points, however, is that the space station, in my belief, will lead to important activities and functions that we cannot even predict today. The space station will represent a fundamentally new and versatile capability to support activities in space in the decade of the 1990's and well beyond.

While definition of a specific station confiquration is yet ahead of us, it might be appropriate to describe conceptually what NASA now considers the station to encompass. We have a little model

over here which has the pieces and parts I am now going to describe. The space station is conceived as a multipurpose, permanent facility in low-Earth orbit that is comprised of both manned and unmanned elements and that significantly enhances the efficiency of our operations in space. As we now see it, the station would consist of a manned base and associated unmanned platforms, oriented to the needs of both science and applications missions and mantended from the base. The base and the platforms would be launched in modular sections carried into orbit in the cargo bay of the shuttle. The shuttle would also be used for logistics resupply and crew rotation. We believe that the enabling capability of the space station can be in place within a decade and for approximately $8 billion in today's dollars.

For fiscal year 1985 we are requesting $150 million for the space station program. We have planned an extensive definition effort with sufficient resources to assure that the program, when hardware development is initiated, will be thoroughly defined, responsive to user requirements, and based on the proper mix of man and machine, incorporating the most advanced technology available. These definition efforts will include an automation plan to utilize the best of both manned and unmanned modes to achieve optimum productivity at the station. The fiscal year 1985 effort will include ongoing assessment of space station utilization requirements and initiation of a number of advanced development test beds to evaluate high leverage space station technology options. The fiscal year 1985 program will comprise the first year of this detailed engineering definition effort which will provide the basis for commitment to the final design for the construction of the space station. Mr. Chairman, we are obviously very enthusiastic about the President's initiative and look forward to working with you to make his vision a reality.

The fiscal year 1985 budget contains a positive step in terms of program outlook and institutional stability. The President's 5-year projections include real growth in NASA activity of 1 percent per year over the 1986–89 time period. The projections do not merely provide for the future year costs of programs proposed for this budget year, as was the previous practice, but include an allowance for the future new initiatives that are essential to a vital program of leadership in space and aeronautics. This approach gives us an opportunity to plan and implement a forward-looking program and provides added incentive to our people to make it happen.

Mr. Chairman, making the space shuttle fully operational and cost effective remains NASA's No. 1 priority for the near future. I am very pleased to report that the space shuttle has continued to perform splendidly and that there have been major achievements in the past year. Perhaps the most important was the first flight of spacelab. The spacelab-1 flight demonstrates that people in space can perform very complex experiments and that real-time corrections and fixes to the experiments can greatly enhance our ability to get important scientific results. The results of spacelab-1 confirmed the capability of scientists in space to perform valuable experimental work and gave credence to our plans for scientific utilization of the space station. The 10-day mission met all of its verification objectives and obtained excellent scientific results. The

flight was also an extremely important example of how complex international collaborative efforts can be successfully carried out. Mr. Chairman, the spacelab was funded and built primarily by the European Space Agency, and one of the people on the first spacelab flight was a European scientist. The spacelab flight drew a great deal of favorable attention in Europe, and there is no doubt in my mind it contributed to easing our relations with the European allies during a particularly critical time last year.

Since our appearance before you last year, we have had four successful shuttle flights. During these flights we flew the second orbiter, *Challenger*; made the first night launch and landing; and flew the first woman, Sally Ride, the first black astronaut, Guy Bluford, and the first two payload specialists including a foreign scientist, Ulf Merbold. We are now looking forward to the selection of private citizens as passengers on future shuttle flights, possibly as early as 1985.

In the past year, we have also conducted our first extra-vehicular activity from the shuttle, and it was very successful. We have learned much about the operational environment of the payload bay, and it is our intent to put this knowledge to good use. This year we plan to conduct the first untethered extra-vehicular activity to test the new manned maneuvering unit. On the following flight, we will retrieve a failed satellite—that is, the flight in April, the Solar Maximum Mission satellite—bring it to the shuttle and attempt to make the necessary repairs, and I think we will be successful. If the repairs are successful, we will redeploy the satellite. If they are not, we will bring the satellite back to the ground for repair and redeploy it on a subsequent shuttle mission. These operations are extremely important, not only because they will permit the extension of the lifetime of of this valuable satellite but also because they will be a dramatic demonstration of the great capability that is inherent in the shuttle system.

Including the SMM repair mission, seven or eight shuttle flights are scheduled for fiscal year 1984. These flights include the first dedicated Department of Defense mission, the first landing at the Kennedy Space Center; the first flight of space shuttle orbiter Discovery; the first autoland; and the deployment of seven commercial communications satellites. A number of science and technology payloads will be flown, including the large format camera and the shuttle imaging radar. These missions will utilize all three of the delivered space shuttle orbiters: Columbia, Challenger, and Discovery. Atlantis, the fourth orbiter, is scheduled for delivery toward the end of 1984.

In fiscal year 1985, the space transportation operations budget provides for 11 space shuttle flights, including 3 dedicated spacelab missions; completion of the TDRSS constellation of 3 orbiting spacecraft; the deployment of 8 communications satellites; the first retrieval of a shuttle-deployed spacecraft, the long duration exposure facility; transition from the conceptual phase of the McDonnell Douglas electrophoresis experimentation to small prototype production plants that will produce products in quantities sufficient to begin testing and marketing; and continued use of the shuttle by the Department of Defense. The STS flight rate will continue to increase toward a rate of 24 per year by fiscal year 1989,

when we expect to launch about 20 from KSC and the remainder from Vandenberg Air Force Base. The first flight from Vandenberg is planned for fiscal year 1986.

In order to make certain that the space shuttle can satisfy the performance requirements and timeliness demanded in the future, the fiscal year 1985 proposed budget includes a program to enhance the performance of the space shuttle propulsion system. The major portion of this program is devoted to improving the space shuttle main engine system, first by increasing the reliability of the system and later by making substantial performance improvements. This will be done by a combination of fine tuning of our designs on certain critical elements of the engine such as bearings and seals, and by taking longer range steps to decrease operating temperatures and pressure under sustained flight at maximum throttle setting. Increases in the engine program are due both to this investment in improved durability and increased investment in spare engines and components. In addition to engine improvements, we are also taking steps to improve the performance of the solid rocket boosters through the use of composite materials to make filament-wound booster cases. Shuttle capability will also be enhanced by the continued NASA/Air Force development of the shuttle/Centaur upper stage, which we will use to launch the Galileo and International Solar Polar missions in 1986.

In view of the successful performance of the shuttle during the past year, I continue to believe that the investments we have made in the space shuttle system will pay off handsomely in the future. The shuttle has become the Nation's primary space launch system. Because of this, we are continuing the program to produce the spare parts required to assure a launch capability that is so important in both the civil and the national security related sectors. We are also continuing the structural spares program. This will make it possible to assemble another orbiter should the decision be made to take this step. For these and many other activities in space transportation systems, we are requesting $3,166 million in fiscal year 1985.

Mr. Chairman, I would now like to turn to NASA's more traditional programs and provide you with a brief report of our accomplishments of the last year and also give you a synopsis of our plans for the future.

In our space science and applications program, the most important achievement was the successful launch of the infrared astronomical satellite [IRAS] a cooperative project of the United States, the Netherlands, and the United Kingdom. The mission was launched in January 1983 and remained operational through December 1983. A number of important discoveries have been announced, but in my opinion two are particularly outstanding. One is the discovery of about 20,000 new asteroids—about 10 times as many as were previously known—with diameters between 1 and 10 miles. This is a truly astonishing number, and it is a result that was generally not expected by the astronomical community. Another equally important discovery of IRAS was that the star Vega is apparently surrounded by a dust cloud that is a prototype for the kind of planetary system that surrounds the Sun. This is the first positive evidence that there may be other stars in our galaxy that

have planetary systems similar to those of the Sun. The large quantity of data that has been generated by the IRAS is now being analyzed. I am confident, Mr. Chairman, that equally significant discoveries will be made in the coming months as we look more carefully through the measurements that have been made by this satellite.

In our fiscal year 1985 budget request of $1,371.5 million for space science and applications, we are proposing several new important initiatives. One is the upper atmosphere research satellite, which is planned for launch in 1989 and will provide detailed measurements of the physical and chemical properties of the upper atmosphere. A particularly important aspect of the upper atmosphere research satellite program is that it will provide information about the molecular species in the upper atmosphere that determine the radiation transport properties in that arena. These properties, in turn, have a strong effect on the world's weather patterns, but perhaps more significantly on the long-term changes that may affect the eventual ability of the earth to continue to support life. I believe that the upper atmosphere research satellite is the most significant new initiative in atmospheric science in many years, and I strongly recommend that you support the program.

Another new initiative is the Mars geoscience/climatology orbiter planned for launch in 1990. The mission will be designed to obtain new geophysical and geochemical information about Mars, especially near the polar regions where not much data is currently available. This mission is the highest priority of a number of relatively low-cost missions referred to as Planetary Observers, which were recommended by the Solar System Exploration Committee to provide a more intensive investigation of specific questions in planetary science. I believe the approach we are taking on this mission will be both an efficient and cost-effective method of planetary exploration.

For several years now, we have developed plans for a program to fly an advanced communication technology satellite called ACTS which is designed to develop advanced communications switching, processing, and antenna technologies, and to regain U.S. technological leadership in this important field. This program was designed to be executed in close collaboration with the communications satellite industry. It has been our purpose, consistent with the President's policy to encourage private sector commercial investments in space, to formulate our programs in such a way as to make it possible for private investors to take part in space activities. The ACTS program is an example of this policy. Recently, private companies have made proposals to build satellites with their own money which will do some of the things that we had planned to do with the ACTS satellite. In view of this development, we have decided not to request funding to support the flight demonstration which had been planned in the ACTS project but to continue the necessary related technology activities on the ground.

In addition to the new initiatives, the proposed fiscal year 1985 space science and applications funding will continue to support a well-balanced and productive program in many areas of science. For example, the Hubble space telescope development activities will be continued, leading to a launch during the second half of

1986; the Galileo development activities will be continued, leading to a launch in 1986; and development will continue on the Venus radar mapper and the gamma ray observatory, both of which are scheduled for 1988 launches. We will continue development of spacelab instrumentation and other shuttle payloads spanning an increasing spectrum of research and development. The fiscal year 1985 budget also continues support for life science and microgravity science and applications, as well as a strong and diverse supporting research effort which provides the foundation for the total NASA science and applications program.

NASA's fiscal year 1985 proposal of $9.5 million for technology utilization will allow continued effort to transfer NASA-developed technology to U.S. industry, the public and Government agencies, at a level made possible by the fiscal year 1984 congressional augmentation.

NASA is requesting a total of $811 million for the Space Tracking and Data Systems program in fiscal year 1985. These funds will provide for the continuation of the vital tracking, command, telemetry, communications, and data processing support to meet the requirements for all NASA flight programs. Tracking and acquisition of data functions are presently accomplished through the use of a worldwide network of ground stations and by the first of a system of three tracking and data relay satellites.

This first TDRS was launched in April 1983 and was deployed into an elliptical orbit as a result of an anomaly during the second-stage burn of the Air Force-provided inertial upper stage, or IUS. Through a series of orbital adjust maneuvers, utilizing the spacecraft's small thrusters, the TDRS-1 was boosted to a geosynchronous orbit.

In the past year, TDRS-1 has successfully supported Landsat-4, the STS-8 mission, and the STS-9/spacelab-1 mission, which received 99 percent of the requested mission data acquisition support. While we are still working with the U.S. Air Force to resolve the IUS problem, we hope to launch the next TDRS in late 1984, with the third launch to follow in 1985.

The fiscal year 1985 space research and technology request of $150 million provides a broad base of long-term, high-risk technology essential to NASA's role of maintaining U.S. preeminence in space. This investment supports Agency goals of improved operational effectiveness of the space transportation system and extended capabilities for U.S. science and applications missions. Further, it provides support to the technology needs of the expanding number of military and commercial space users. Of particular significance in this year's NASA program are advanced technology capabilities derived from ongoing research which will be focused in support of space station definition efforts.

NASA is also requesting $342.2 million in fiscal year 1985 for aeronautics research and technology to provide the technology advances critical to the continued preeminence of U.S. civil and military aviation. A strong, proven base of technology will be required to maintain a superior military capability and to enhance our competitive position in the world aviation marketplace. The fiscal year 1985 budget request provides a forward-looking program in both disciplinary and focused systems research that is built upon

NASA's unique in-house capabilities and utilizes the research and technology talents of the industry.

NASA's fiscal year 1985 construction of facilities request of $160 million will provide for minimum essential facility needs, with particular emphasis on exploiting the shuttle's capabilities, enhancing key research facilities for aeronautics and space technology development, and improving space communications capabilities. It includes provision for a new facility at the Ames Research Center to house the numerical aerodynamic simulator now under development, as well as funding to complete construction of two key facilities at the Kennedy Space Center—a solid rocket booster assembly and refurbishment facility and a logistics facility to be used in conjunction with the shuttle processing activities. As part of NASA's construction of facilities request, we are requesting an increase in the funding limits for individual projects in the minor facilities program.

Mr. Chairman, I am very pleased to report that the NASA institution is fully prepared to support the President's budget initiatives. Perhaps, the most important factor is that with the support of this administration and the cooperation of the Congress, the decline in the civil service complement assigned to NASA has been stopped. For the past 2 years, the NASA civil service complement has been stable at approximately 22,000 positions, and our fiscal year 1985 research and program management budget request of $1,331 million will allow us to continue with this number of people into the future. This stability has had the important consequence that in 1983 we were able to hire almost 600 recent science and engineering graduates. With the civil service complement we are proposing, we hope to be able to hire several hundred new science and engineering graduates next year as well. There is no doubt whatsoever that our ability to bring in so many new people will have a profound, positive influence on the future of NASA. The importance of this in-house capability has been well recognized in many studies, including the recent one carried out by the Office of Science and Technology Policy under the chairmanship of Mr. David Packard. This study explicity recognized the importance of healthy Federal laboratories to the economic health and national security of the United States, and we endorse and support its recommendations.

An Agency-wide productivity improvement and quality enhancement program emphasis last year is producing several long-term initiatives for streamlining our administrative processes, improving contract management, and enhancing support for science and mathematics education.

In addition to people, we must also look to the adequate operation and maintenance of our physical plant. Accordingly, NASA's fiscal year 1985 R&PM request includes an increase of $10 million to augment day-to-day recurring operational and preventive maintenance activities. I believe this is extremely important, if we are to execute the programs that we have in mind.

Mr. Chairman, I have attempted to provide you and the members of the subcommittee with a short overview of the administration's fiscal year 1985 program for NASA. We believe that it is an excellent program and will continue to insure our Nation's leadership in

space and aeronautics in the coming years. The program also provides a new vision for the future which is both realistic and farsighted.

I would be remiss, Mr. Chairman, if I did not take this opportunity to thank this subcommittee for its continued interest and support. Without your help and leadership over the past years, it would not have been possible for us to formulate the program that I am presenting today.

Thank you very much, Mr. Chairman. I would, of course, be pleased to answer questions.

[The prepared statement, plus answers to questions asked of Mr. Beggs follows:]

Statement of

James M. Beggs
Administrator

National Aeronautics and Space Administration

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Distinguished Members of the Subcommittee:

It is a pleasure for me to appear before this Subcommittee to present President Reagan's budget request for NASA for FY 1985. The total Agency request is $7.5 billion, of which $2.4 billion is for Research and Development, including $342.4 million for Aeronautics Research and Technology; $3.6 billion for Space Flight, Control and Data Communications; $160 million for Construction of Facilities; and $1.3 billion for Research and Program Management. A chart summarizing NASA's FY 1985 budget request is appended to this statement.

In his State of the Union message to Congress last week, President Reagan outlined a bold new initiative for the United States that will maintain and ensure, during the decade of the 1990's and beyond, our hard won position of leadership in space. The President's initiative is a permanently manned Space Station to be in operation within a decade. As a fundamental element of his vision for this Nation's future, the Space Station will:

- reflect and contribute to America's commitment to research, technology and productivity;
- be a peaceful, visible demonstration of U.S. strength and commitment to leadership;
- implement the clear direction the civil space program has needed and found in the President's National Space Policy set forth in July of 1982.

The time for Space Station is ripe -- the agenda for tasks which can be undertaken and enhanced using the unique capabilities of the Space Station is full, and both U.S. industry and the NASA institution are fully prepared to implement the President's initiative. The Station is, I believe, the next logical step in space.

The idea of a Space Station Mr. Chairman, is not new; however, a combination of circumstances makes the President's initiative especially timely. The most important reason to begin

a Space Station now is that the Space Shuttle is approaching fully operational status. After a ten year development program, we now have the capability to reach low Earth orbit routinely. To maximize the unique advantages provided by the environment of space, we need to establish a permanent presence that enables us to work in space full time and fully utilizes the capabilities of the Space Shuttle. Without the capability of the Shuttle, it would be impossible to establish the "more permanent presence in space" referenced by the President on July 4, 1982, in his National Space Policy statement. A second reason is that the operations we have conducted with the Shuttle have stimulated great interest in the private sector to look toward investments in future space activities. The construction of a Space Station is necessary to create the facilities that will greatly encourage such investment, and to stimulate new technology that will spin off into the U.S. economy. Finally, the Shuttle has also stimulated great international interest in the U.S. Space Program, as evidenced by the overwhelming reception of the "Enterprise" in Europe last summer and the recent highly successful flight of the Spacelab. As the President stated, we will plan the Space Station program in such a way that it will be possible for our friends and allies around the world to participate with us in taking this major step.

Based upon NASA and industry analyses over the past 18 months, the Space Station program will serve a number of functions, such as:

- a laboratory in space, for the conduct of science and the development of new technologies;
- a permanent observatory, to look down upon the Earth and out at the universe;
- a transportation node where payloads and vehicles are stationed, processed and propelled to their destinations;
- a servicing facility, where these payloads and vehicles are maintained, and if necessary, repaired;
- an assembly facility where, due to ample time on orbit and the presence of appropriate equipment, large structures are put together and checked out;
- a manufacturing facility where human intelligence and the servicing capability of the Station combine to enhance commercial opportunities in space;
- a storage depot where payloads and parts are kept on orbit for subsequent deployment; and,
- a staging base for more ambitious future missions.

Perhaps more important than any of these individual points, however, is that the Space Station, in my belief, will lead to important activities and functions that we cannot even predict today. The Space Station will represent a fundamentally new and versatile capability to support activities in space in the decade of the 1990's and beyond.

While definition of a specific Station configuration is yet ahead of us, it might be appropriate to describe conceptually what NASA now considers the Station to encompass. A Space Station is conceived as a multi-purpose, permanent facility in low-Earth orbit, that is comprised of both manned and unmanned elements and that significantly enhances the efficiency of our operations in space. As we now see it the Station would consist of a manned base and associated unmanned platforms, oriented to the needs of both science and applications missions, and man-tended from the base. The base and the platforms would be launched in modular sections carried into orbit in the cargo bay of the Shuttle. The Shuttle would also be used for logistics resupply and crew rotation. We believe that the enabling capability of the Space Station can be in place within a decade and for approximately $8 billion in today's dollars.

For FY 1985 we are requesting $150.0 million for the Space Station program. We have planned an extensive definition effort with sufficient resources to assure that the program, when hardware development is initiated, will be thoroughly defined, responsive to user requirements, and based on the proper mix of man and machine, incorporating the most advanced technology available. These definition efforts will include an automation plan to utilize the best of both manned and unmanned modes to achieve optimum productivity at the Station. The FY 1985 effort will include ongoing assessment of Space Station utilization requirements and initiation of a number of advanced development test beds to evaluate high leverage space station technology options. The FY 1985 program will comprise the first year of this detailed engineering definition effort which will provide the basis for commitment to the final design for the construction of the Space Station. Mr. Chairman, we are very enthusiastic about the President's initiative, and look forward to working with you to make this vision a reality.

The FY 1985 budget contains a positive step in terms of program outlook and institutional stability. The President's five year projections include real growth in NASA activity of one percent per year over the 1986-1989 period. The projections do not merely provide for the future year costs of programs proposed for the budget year, as was the previous practice, but include an allowance for the future new initiatives that are essential to a vital program of leadership in Space and Aeronautics. This approach gives us an opportunity to plan and implement a forward looking program and provides added incentive to our people to make it happen.

Mr. Chairman, making the Space Shuttle fully operational and cost-effective remains NASA's number one priority. I am very pleased to report that the Space Shuttle has continued to perform splendidly and that there have been major achievements in the past year. Perhaps the most important one was the first flight of Spacelab. The Spacelab-1 flight demonstrated that people in space can perform very complex experiments and that real-time corrections and fixes to the experiments can greatly enhance our ability to get important scientific results. The results of Spacelab-1 confirmed the capability of scientists in space to perform valuable experimental work and gave credence to our plans for scientific utilization of the Space Station. The ten-day mission met all of its verification objectives and obtained excellent scientific results. The flight was also an extremely important example of how complex international collaborative efforts can be successfully carried out. Mr. Chairman, the Spacelab was funded and built primarily by the European Space Agency and one of the people on the first Spacelab flight was a European scientist. The Spacelab flight drew a great deal of favorable attention in Europe and, there is no doubt in my mind, it contributed to easing our relations with our European allies during a particularly critical time last year.

Since our appearance before you last year, we have had four successful Shuttle flights. During these flights, we flew the second orbiter, Challenger; made the first night launch and landing; and flew the first woman (Sally Ride), the first black (Guy Bluford) and the first two payload specialists including a foreign scientist (Ulf Merbold). We are now looking forward to the selection of private citizens as passengers on future Shuttle flights, possibly as early as 1985.

In the past year, we have also conducted our first extra-vehicular activity from the Shuttle and it was very successful. We have learned much about the operational environment of the payload bay and it is our intent to put this knowledge to good use. This year we plan to conduct the first untethered extra-vehicular activity to test the new Manned Maneuvering Unit. On the following flight, we will retrieve a failed satellite (the Solar Maximum Mission satellite), bring it to the Shuttle and attempt to make the necessary repairs. If the repairs are successful, we will redeploy the satellite. If they are not, we will bring the satellite back to the ground for repair and redeploy it on a subsequent Shuttle mission. These operations are extremely important, not only because they will permit the extension of the lifetime of this valuable satellite, but also because they will be a dramatic demonstration of the great capability that is inherent in the Shuttle system.

Including the SMM repair mission, seven or eight Shuttle flights are scheduled for FY 1984. These flights include the first dedicated Department of Defense mission; the first landing at the Kennedy Space Center; the first flight of Space Shuttle Orbiter "Discovery;" the first autoland; and the deployment of

seven commercial communications satellites. A number of science and technology payloads will be flown, including the Large Format Camera and the Shuttle Imaging Radar. These missions will utilize all three of the delivered Space Shuttle Orbiters: Columbia, Challenger, and Discovery. Atlantis, the fourth orbiter, is scheduled for delivery toward the end of 1984.

In FY 1985, the Space Transportation Operations budget provides for 11 Space Shuttle flights, including three dedicated Spacelab missions; completion of the TDRSS constellation of three orbiting spacecraft; the deployment of eight communications satellites; the first retrieval of a Shuttle-deployed spacecraft, the Long Duration Exposure Facility; transition from the conceptual phase of the McDonnell Douglas electrophoresis experimentation to small prototype production plants that will produce products in quantities sufficient to begin testing and marketing; and continued use of the Shuttle by the Department of Defense. The STS flight rate will continue to increase toward a rate of 24 per year by FY 1989, when we expect to launch about 20 from KSC and the remainder from Vandenberg Air Force Base. The first flight from Vandenberg is planned for FY 1986.

In order to make certain that the Space Shuttle can satisfy the performance requirements and timelines demanded in the future, the FY 1985 proposed budget includes a program to enhance the performance of the Space Shuttle propulsion system. The major portion of this program is devoted to improving the Space Shuttle Main Engine system, first by increasing the reliability of the system and later by making substantial performance improvements. This will be done by a combination of fine tuning of our designs on certain critical elements of the engine such as bearings and seals, and by taking longer-range steps to decrease operating temperatures and pressures under sustained flight at maximum throttle setting. Increases in the engine program are due both to this investment in improved durability and increased investment in spare engines and components. In addition to engine improvements, we are also taking steps to improve the performance of the Solid Rocket Boosters through the use of composite materials to make filament wound booster cases. Shuttle capability will also be enhanced by the continued NASA/Air Force development of the Shuttle/Centaur upper stage, which we will use to launch the Galileo and International Solar Polar missions in 1986.

In view of the successful performance of the Shuttle during the past year, I continue to believe that the investments we have made in the Space Shuttle system will pay off handsomely in the future. The Shuttle has become the Nation's primary space launch system; because of this, we are continuing the program to produce the spare parts required to assure a launch capability that is so important in both the civil and the national security related sectors. We are also continuing the structural spares program; this will make it possible to assemble another orbiter should the decision be made to take this step. For these and

many other activities in Space Transportation Systems, we are requesting $3166.0 million in FY 1985.

Mr. Chairman, I would now like to turn to NASA's more traditional programs and provide you with a brief report of our accomplishments of the last year and also give you a synopsis of our plans for the future. In our Space Science and Applications program, the most important achievement was the successful launch of the Infrared Astronomical Satellite (IRAS), a cooperative project of the United States, the Netherlands and the United Kingdom. The mission was launched in January 1983, and remained operational through December 1983. A number of important discoveries have been announced, but in my opinion two are particularly outstanding. One is the discovery of about 20,000 new asteroids -- about ten times as many as were previously known --with diameters between one and ten miles. This is a truly astonishing number and it is a result that was generally not expected by the astronomical community. Another equally important discovery of IRAS was that the star Vega is apparently surrounded by a dust cloud that is a prototype for the kind of planetary system that surrounds the Sun. This is the first positive evidence that there may be other stars in our galaxy that have planetary systems similar to those of the Sun. The large quantity of data that has been generated by the IRAS is now being analyzed. I am confident, Mr. Chairman, that equally significant discoveries will be made in the coming months as we look more carefully through the measurements that have been made by this satellite.

In our FY 1985 budget request of $1371.5 million for Space Science and Applications, we are proposing several new important initiatives. One is the Upper Atmosphere Research Satellite, which is planned for launch in 1989, and will provide detailed measurements of the physical and chemical properties of the upper atmosphere. A particularly important aspect of the Upper Atmosphere Research Satellite program is that it will provide information about the molecular species in the upper atmosphere that determine the radiation transport properties in that arena. These properties, in turn, have a strong effect on the world's weather patterns, but perhaps more significantly on the long-term changes that may affect the eventual ability of the Earth to continue to support life. I believe that the Upper Atmosphere Research Satellite is the most significant new initiative in atmospheric science in many years, and I strongly recommend that you support the program.

Another new initiative is the Mars Geoscience/Climatology Orbiter planned for launch in 1990. The mission will be designed to obtain new geophysical and geochemical information about Mars, especially near the polar regions where not much data is available. This mission is the highest priority of a number of relatively low-cost missions referred to as "Planetary Observers," which were recommended by the Solar System Exploration Committee to provide a more intensive investigation

of specific questions in planetary science. I believe the approach we are taking on this mission will be both an efficient and cost-effective method of planetary exploration.

For several years now, we have developed plans for a program to fly an Advanced Communications Technology Satellite called ACTS which is designed to develop advanced communications switching, processing, and antenna technologies; and to regain U.S. technological leadership in this important field. This program was designed to be executed in close collaboration with the communications satellite industry. It has been our purpose, consistent with the President's policy to encourage private sector commercial investments in space, to formulate our programs in such a way as to make it possible for private investors to take part in space activities. The ACTS program is an example of this policy. Recently, private companies have made proposals to build satellites with their own money which will do some of the things that we had planned to do with the ACTS satellite. In view of this development, we have decided not to request funding to support a flight demonstration which had been planned in the ACTS project, but to continue the necessary related technology activities on the ground.

In addition to the new initiatives, the proposed FY 1985 Space Science and Applications funding will continue to support a well-balanced and productive program in many areas of science. For example, the Hubble Space Telescope development activities will be continued, leading to a launch during the second half of 1986; the Galileo development activities will be continued, leading to a launch in 1986; and development will continue on the Venus Radar Mapper and the Gamma Ray Observatory, both of which are scheduled for 1988 launches. We will continue development of Spacelab instrumentation and other Shuttle payloads spanning an increasing spectrum of research and development. The FY 1985 budget also continues support for Life Science and Microgravity Science and Applications, as well as a strong and diverse supporting research effort which provides the foundation for the total NASA science and applications program.

NASA's FY 1985 proposal of $9.5 million for Technology Utilization will allow continued effort to transfer NASA-developed technology to U.S. industry, the public and Government agencies, at a level made possible by the FY 1984 Congressional augmentation.

NASA is requesting a total of $811.0 million for the Space Tracking and Data Systems program in FY 1985. These funds will provide for the continuation of the vital tracking, command, telemetry, communications, and data processing support to meet the requirements for all NASA flight programs. Tracking and acquisition of data functions are presently accomplished through the use of a worldwide network of ground stations and by the first of a system of three Tracking and Data Relay Satellites.

This first TDRS was launched in April 1983, and was deployed into an elliptical orbit as a result of an anomaly during the second stage burn of the Air Force-provided Inertial Upper Stage (IUS). Through a series of orbital adjust maneuvers, utilizing the spacecraft's small thrusters, the TDRS-1 was boosted to a geosynchronous orbit.

In the past year, TDRS-1 has successfully supported Landsat-4, the STS-8 mission, and the STS-9/Spacelab-1 mission, which received 99 percent of the requested mission data acquisition support. While we are still working with the USAF to resolve the IUS problem, we hope to launch the next TDRS in late 1984, with the third TDRS launch to follow in 1985.

The FY 1985 Space Research and Technology request of $150.0 million provides a broad base of long-term, high-risk technology essential to NASA's role of maintaining U.S. preeminence in space. This investment supports Agency goals of improved operational effectiveness of the space transportation system and extended capabilities for U.S. science and applications missions. Further, it provides support to the technology needs of the expanding number of military and commercial space users. Of particular significance in this year's NASA program are advanced technology capabilities derived from ongoing research which will be focused in support of Space Station definition efforts.

NASA is requesting $342.4 million in FY 1985 for Aeronautics Research and Technology to provide the technology advances critical to the continued preeminence of U.S. civil and military aviation. A strong, proven base of technology will be required to maintain a superior military capability and to enhance our competitive position in the world aviation marketplace. The FY 1985 budget request provides a forward-looking program in both disciplinary and focused systems research that is built upon NASA's unique in-house capabilities and utilizes the Research and Technology talents of the industry.

NASA's FY 1985 Construction of Facilities request of $160 million will provide for minimum essential facility needs, with particular emphasis on exploiting the Shuttle's capabilities, enhancing key research facilities for aeronautics and space technology development, and improving space communications capabilities. It includes provision for a new facility at the Ames Research Center to house the Numerical Aerodynamic Simulation (NAS) activities now under development, as well as funding to complete construction of two key facilities at the Kennedy Space Center -- a solid rocket booster assembly and refurbishment facility and a logistics facility to be used in conjunction with the Shuttle Processing activities. As part of NASA's Construction of Facilities request, we are requesting an increase in the funding limits for individual projects in the minor facilities program.

Mr. Chairman, I am very pleased to report that the NASA institution is fully prepared to support the President's budget initiatives. Perhaps the most important factor is that with the support of this Administration and the cooperation of the Congress, the decline in the civil service complement assigned to NASA has been stopped. For the past two years, the NASA Civil Service complement has been stable at approximately 22,000 positions and our FY 1985 Research and Program Management budget request of $1331.0 million will allow us to continue with this number of people into the future. This stability has had the important consequence that in 1983 we were able to hire almost 600 recent science and engineering graduates. With the civil service complement we are proposing, we hope to be able to hire several hundred new science and engineering graduates next year as well. There is no doubt whatsoever that our ability to bring in so many new people will have a profound, positive influence on the future of NASA. The importance of this in-house capability has been well-recognized in many studies, including the recent one carried out by the Office of Science and Technology Policy under the chairmanship of Dr. David Packard. This study explicitly recognized the importance of healthy Federal laboratories to the economic health and national security of the U.S. and we endorse and support its recommendations.

An Agency-wide Productivity Improvement and Quality Enhancement Program emphasis last year is producing several long-term initiatives for streamlining our administrative processes, improving contract management, and enhancing support for science and mathematics education.

In addition to people, we must also look to the adequate operation and maintenance of our physical plant. Accordingly, NASA's FY 1985 R&PM request includes an increase of $10 million to augment day-to-day recurring operational and preventive maintenance activities. I believe this is extremely important if we are to execute the programs that we have in mind.

Conclusion

Mr. Chairman, I have attempted to provide you and the Members of the Subcommittee with a short overview of the Administration's FY 1985 program for NASA. I believe that it is an excellent program that will continue to ensure our Nation's leadership in space and aeronautics in the coming years. The program also provides a new vision for the future which is both realistic and farsighted. I would be remiss, Mr. Chairman, if I did not take this opportunity to thank this Subcommittee for its continued interest and support. Without your help and leadership over the past years, it would not have been possible for us to formulate the program that I am presenting today.

Mr. Chairman, I would now be pleased to answer any questions that you and other Members of the Subcommittee might have.

National Aeronautics and Space Administration

BUDGET SUMMARY

(dollars in millions)

RESEARCH AND DEVELOPMENT	FY 1983	FY 1984	FY 1985
Space Station[a/]	(4.0)	(14.0)	150.0
Space Transportation Capability Development	415.5	431.7	361.4
Physics and Astronomy	470.3	567.6	677.2
Life Sciences	55.7	58.0	63.3
Planetary Exploration	186.4	217.4	286.9
Space Applications	347.7	291.0	344.1
Space Science and Applications	1061.0	1134.0	1371.5
Technology Utilization	9.0	9.0	9.5
Aeronautical Research and Technology	280.0	302.3	342.4
Space Research and Technology	124.5	137.0	150.0
Tracking and Data Advanced Systems	13.4	14.2	15.3
TOTAL RESEARCH AND DEVELOPMENT	**1902.5**	**2028.2**	**2400.1**
SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS [b/]			
Shuttle Production and Operational Capability	1725.8	1649.3	1485.6
Space Transportation Operations	1421.7	1452.0	1339.0
Space and Ground Network, Communications & Data Systems	485.5	674.0	795.7
TOTAL SPACE FLIGHT, CONTROL & DATA COMMUNICATIONS	**3633.0**	**3775.3**	**3600.3**
CONSTRUCTION OF FACILITIES	103.5	155.5	160.0
RESEARCH AND PROGRAM MANAGEMENT	1197.4	1258.5 [c/]	1331.0
TOTAL	**6836.4**	**7217.5**	**7491.4**
Outlays	6663.9	7068.2	7370.0

a/ In FY 1983, the Space Station Activity was included in Space Transportation Capability Development. In FY 1984, $6.0 million was included in Space Transportation Capability Development, $2.0 million in Space Science and Applications and $6.0 million in Space Research and Technology.

b/ Prior to FY 1984, these programs were included in the Research and Development appropriation.

c/ Includes $20.0 million for proposed pay raise supplemental.

Questions submitted by Chairman Volkmer during the February 1, 1984, hearing at which Mr. Beggs testified on NASA's FY 1985 budget.

QUESTION A-1:

Within the broad area of the Space Transportation System, some have suggested that the fifth orbiter and the Space Station are competitive priorities.

a. What is the relative priority of the fifth orbiter vis-a-vis the Space Station?

b. If you do not believe these priorities are competitive, why not?

ANSWER A-1:

We do not view the initiation of a Space Station program as a competitive priority with the procurement of additional orbiters. On the contrary, with the growing maturity of the Space Transportation System, it is now logical to begin the Space Station program in order to fully exploit the capabilities of the Shuttle and retain U.S. leadership in space in the 1990's.

As far as a fifth orbiter is concerned, we have looked at that question very carefully for the last several years. We still hold the position that, at this time, projected traffic demands indicate that the currently approved four orbiter fleet will be sufficient for at least the next several years. However, we are retaining a basic capability to produce additional orbiters in the future, should a decision be made to do so. This capability is being maintained by the structural spares program initiated this year and by the ongoing orbiter logistics program.

We believe that the President's FY 1985 Space Program presents a well-balanced course of action for the Nation and that the priorities are reflected in the budget recommendations.

QUESTION A-2:

How would the addition of a fifth orbiter affect the projected flight rate per vehicle necessary to recover fixed costs? How would it affect costs to users?

ANSWER A-2:

The addition of a fifth Space Shuttle orbiter to the fleet would allow the increase of about seven to eight flights per year. For a four-orbiter operation

at KSC and a one-orbiter operation at VAFB, the annual flight rate capacity of the fleet could increase from 24 flights per year to about 31 flights per year, or an increase of 33 percent. If the demand for launches grows to meet the capability, then the fixed costs of operation would be spread over a larger number of flights, and the cost of each Shuttle mission would be correspondingly reduced. On the other hand, if the demand did not increase, the carrying costs of maintaining a larger fleet would increase as well and there would be no reduction in operational costs. Costs to the user (customers) would reflect the impact of the level of traffic discussed above.

QUESTION A-3:

Do you believe we will need a fifth orbiter? When in the future do you anticipate a budget request for a fifth orbiter?

ANSWER A-3:

NASA has continued to study the need for additional Space Shuttle orbiters. These examinations have focused upon impacts of the loss or extended downtime of one of the currently authorized four orbiter fleet and on the likelihood of future traffic growth beyond current capability. These studies have indicated that the current fleet will be sufficient for at least the remainder of this decade. However, concern was expressed on the need for assurance to accommodate unscheduled maintenance or accidents causing extensive damage or loss of an orbiter.

For this reason, an orbiter structural spares program was initiated in FY 1984. This program provides additional assurance in maintaining Shuttle operations and also protects orbiter production capability through FY 1985. This program along with the operational spares program, in our judgment, represents the optimal approach to support of the planned orbiter fleet and the option to proceed with full production of an additional orbiter at a later date. This issue will be reviewed again as part of the FY 1986 budget formulation process.

QUESTION A-4:

We all understand that every transportation mode (rail, truck, ship, and aircraft) experiences attrition over time. Though we hope that the STS never incurs an accident that results in the loss of an orbiter, does it seem reasonable to you to base the long term operation of something as critically important as this country's national space launch

capability on the assumption that attrition will never occur?

Is this not reason enough to justify the purchase of a fifth orbiter?

ANSWER A-4:

It is not reasonable to assume that some sort of accident to an orbiter will never occur. What is not known is the severity of the accident. The orbiter structural spares program initiated in FY 1984 provides protection against a non-catastrophic but severe damage to the structure as well as reducing lead time to procure an additional orbiter should that be necessary. Additionally, this program combined with the ongoing spares procurements protect orbiter production capability and maintain the option of adding another orbiter without excessive start-up costs.

QUESTION A-5:

How much of the orbiter production base will be lost be delaying the decision to buy the fifth orbiter for another year?

a. How much will a one year delay in the decision to buy the fifth orbiter increase the production cost of that vehicle?

b. Given these facts and NASA's past strong arguments for the need for a fifth orbiter, wouldn't it be more reasonable to begin production in 1985 rather than delaying it for another year?

ANSWER A-5:

The balance of funding between the in-house effort and subcontractors in the FY 1984 to FY 1986 timeframe retains many essential elements of the orbiter build capability. However, the Downey/Palmdale assembly workforce will be phasing down with the delivery of Atlantis, scheduled for December, 1984. However, this will be partially offset by the planned upgrading of Columbia, scheduled for next year. We will experience some loss of production capability in the final assembly area. Operational and structural spares provisions have been made to minimize the loss of capability with subcontractors.

a. Our current assessment shows a one-year delay in buying a fifth orbiter would result in an additional cost of approximately $200 million, including inflation.

b. The discussion above does not support the need for starting a fifth orbiter in FY 1985. A key issue is the requirements substantiating the need for additional capacity. The potential of a catastrophic accident or other problem which would require the replacement of one of the existing four orbiter fleet has been addressed previously. It is true, the delay in building the fifth orbiter will result in some additional cost estimated at approximately ten percent. However, we believe the cost associated with gapping has been minimized through the provisioning strategies we are following for structural and operational spares. Additionally, it is our position that, in the long run, demonstrating a firm need for a fifth orbiter before embarking on its development is the most "cost prudent" way to approach this problem.

QUESTION A-6

Extended Duration Orbiter

We have been told by NASA that extending the Shuttle's on-orbit stay capability to in excess of 14 days would permit significant new research results to be achieved. Scientists have told us that such extensions would be "pure gold" and NASA has indicated that the costs of extending orbiter stay time to around 20 days could run as low as $78 million. Though the Space Station will of course permit much longer on orbit stay times, it will be limited to a single (probably 28° inclination) orbit. Would it not seem reasonable to make this modest investment in expending the orbiter's capability so that experimenters can conduct adequate research in polar or other orbits that are different from the one occupied by the Space Station?

ANSWER A-6

We have for a number of years looked forward to meeting the initial design goals for an extended duration orbiter and have identified three areas where a mission duration capability of 14 days could be useful:

(1) Vapor Solution Crystal Work
(2) Complete Solar Track--Entire Pass
(3) Full Earth Coverage, Polar Orbit

Our analysis to date indicates that it would be very difficult to justify the major expenditure of funds, control and avionics changes which would be necessary to extend the duration beyond 20 days with no identified critical requirements for that time which could not be met more effectively by the Space Station.

Therefore, we intend to allocate $1.5 million to look further at extended duration and expanding the basic capabilities of the Shuttle. This will include how we can bring the cost down; the most effective way to implement potential changes; and studying the options to systematically trade off each of the user community needs, especially on the scientific side.

QUESTION A-7

Last December, the NASA Advisory Council made a strong recommendation that the operating budgets, facilities, and personnel required to support the Space Shuttle be "fenced" from the rest of NASA. It was argued that such an action would: speed the transition to more efficient operations; help reduce costs; and ease the eventual transfer of STS operations to the private sector or some new governmental operating agency. What is NASA's position on this recommendation?

ANSWER A-7

Although the Shuttle program has successfully entered the operational era by demonstrating its reliability and versatility, there are a number of reasons that preclude an organizational change of this nature at this time. From a program maturity standpoint, the current organizational structure within NASA should remain intact to ensure that a stable and dependable system is provided.

Several factors lead to this conclusion:

o We have yet to complete the orbiter fleet and modifications to Columbia remain to be done.

o The complete set of ground support and launch site equipment is over two years away from readiness to support the desired turnaround intervals.

o Cargo/Shuttle interface processes require increased standardization.

o The maintenance and spares program for the higher flight rates is not yet in place.

o The main engine still requires extensive maintenance and development of an acceptable design life has not yet been accomplished.

In light of these factors, plus the problems experienced during the first few operational flights, NASA believes that the changes in appropriation structure mandated in FY 1984, where Shuttle

Production and Operational Capability and Space Transportation Operations, were established in a separate appropriation (Space Flight, Control and Data Communications) is a reasonable initial step in the direction proposed by the NAC.

With regard to reorganization to increase efficiency and reduce costs, major steps have been taken at the operating level by consolidating the base operations and launch processing activities at KSC under two single contractors. Also, consolidating the JSC multicontractor operations is being planned. However, any move to reorganize the current structure for the purpose of transferring STS operations outside of NASA should be deferred.

QUESTION A-8:

What is being done by NASA to reduce the integration time, integration costs, and complicated and cumbersome procedures required for a user to fly a payload on the Shuttle?

ANSWER A-8:

Steps are underway at JSC to substantially reduce the mission integration time, cost, and complexity. The mission integration/flight production process which formerly required about 36 months has now been reduced to about a 22-month cycle. Additional improvements in the efficiency of this process should result in continued compression of the process as the program matures and more repeat payloads are flown.

Documentation requirements are being simplified and streamlined, and redundancy is being eliminated. Also the review process has been consolidated, resulting in fewer iterations and revisions of mission documentation.

Actions have been taken at KSC to reduce STS cargo processing time and associated costs and to improve overall efficiency. Procedural documentation requirements have been streamlined, including consolidation of CCAFS and KSC safety manuals; a single point of contact for customers has been established, the Launch Site Support Manager; and cargo-to-orbiter interface test requirements have been reassessed. On STS 41-B a significant reduction in the number of interface verification tests was made. NASA's goal is to continue to reduce cargo processing flow times, working closely with our customers to achieve this goal.

QUESTION A-9:

What have you learned from this that can be applied to the station?

ANSWER A-9:

It is expected that STS cargo processing and mission integration experiences and the resulting enhancements will be applied to future Space Station activities. For instance, the operational processing procedures that have evolved for STS cargo processing will increase the likelihood that initial Space Station element processing operations will be efficient.

Aerospace Safety Advisory Panel

QUESTION A-10:

Please elaborate on the most recent report of the Aerospace Safety Advisory Panel related to the Space Shuttle. Are you aware of any unresolved safety issues concerning the Space Shuttle?

ANSWER A-10:

The Aerospace Safety Advisory Panel in their 1983 Annual Report made several significant recommendations with regard to Shuttle safety:

1. Augment quality assurance with motivational emphasis. The dominant goal should now be operational suitability rather than performance. This has been ongoing and is being further expanded.

2. Conduct a complete review of the landing gear. A complete brake review is now being performed by NASA and industry experts.

3. A logistic system requires an overall maintenance plan, a clearly defined Shuttle Processing Contractor (SPC) role, and should include all STS elements. Lockheed has been selected as the SPC contractor and has taken over full responsibility as of early February. These items are being addressed as Lockheed develops procedures.

4. Expansion of the Shuttle operational envelope requires the derivation of a new set of loads and their validation through flight data. Validation began in July, 1983, and is still in progress. Flight loads of 6.0 are being investigated and used at this time.

5. A major reduction in landing speed and improvement in pitch control should be explored. LaRC has researched use of canards and is still being evaluated by the program office.

These recommendations are under continuous review and the panel will be advised as further action is taken.

QUESTION A-11:

Recently, Congress has been presented with conflicting views on "Administrative policy" from NASA and OSTP on several major issues.

a. What do you think is the origin of this difference?

b. Why isn't the Administration able to "get its act together" and articulate a common position?

ANSWER A-11:

We have just completed a long interagency process to prepare options for the President's decision on Space Station and other aspects of space policy. During that process, there was naturally a considerable diversity expressed among agencies with respect to their views and interests. These were reflected both formally and informally in various communications to the Hill and in articles in the press. Now that the President has made his decision, the agencies of the Administration are supporting the President's program.

QUESTION A-12:

In order to maintain U.S. leadership in the face of international competition, it is essential to construct a clear policy road map.

a. What do you consider to be the major unifying goal of the U.S. space program?

b. Recently, national space policy statements have been of a classified nature. What useful purpose could a classified policy have in maintaining U.S. leadership in civilian space activities and in ensuring the use of space for the benefit of all mankind?

ANSWER A-12:

The major objectives of the U.S. space policy, as expressed by the President in July, 1982, have not

changed. We wish to:

-- strengthen the security of the United States;

-- maintain U.S. space leadership;

-- obtain economic and scientific benefits through the exploitation of space;

-- expand U.S. private sector investment and involvement in civil space and space related activities;

-- promote international cooperative activities in the national interest; and

-- cooperate with other nations in maintaining the freedom of space for activities which enhance the security and welfare of mankind.

A number of initiatives have been taken by the Administration in the FY 1985 budget and in the policy development process in order to move these aims forward. The President's decision to direct NASA to build a permanently-manned Space Station within a decade was a critical element in these initiatives. It is an essential step in maintaining U.S. leadership. It will provide extremely fruitful ground for significant international cooperation. It will open the way to important advances in science and technology and it will provide significant opportunities for commercial uses of outer space.

Our National Space Policy notes that the U.S. space program consists of two parts: civil and national security. Some policy statements related to the national security portion of the U.S. space program are classified.

QUESTION A-13:

Under the present Administration, the use of the Senior Interagency Group structure has played a major policy role in setting national space policy. This is of concern to Congress since the formulation of policy and accountability for policy recommendations are somewhat obscure.

a. What role does NASA play in the Senior Interagency Group on Space?

b. What policy areas does NASA reserve for itself?

ANSWER A-13:

NASA is a major participator in the Senior Interagency Group (Space). NASA has chaired or

co-chaired a number of the Senior Interagency Group activities related to the civil space program. Since these issues have important policy, program and budget implications for a number of agencies, the inclusion of other agencies in the process is essential. NASA has and will continue to be a leading voice in formulating and articulating those areas of space policy that are within our statutory mandate. However, it will often be the case that these areas are also of interest to other agencies and when that is true, we anticipate that the Senior Interagency Group (Space) will be forum for bringing all views forward for decision.

QUESTION A-14:

Recently, the OSTP initiated a major initiative to define appropriate civilian, Federal, and interagency roles in performing aeronautical research and development in order to maintain U.S. preeminence in aviation.

a. Would a similar effort in space systems research be of benefit in identifying proper roles for NASA, DOD, and the private sector?

b. How do you ensure that NASA research in space R&D is properly coordinated with other agencies and with the private sector?

ANSWER A-14:

a. In June, 1982, OSTP and the National Security Council produced NSSDD 42 (classified and unclassified versions) as a national policy base for space research and development. The OSTP examination of the aeronautics research and development role for NASA was subsequently initiated to provide similar policy guidance for aeronautics. The recent executive announcement calling for a implementation of a vigorous space program provides a framework for U.S. preeminence in space. As a result, we at NASA have been reviewing potential actions as exemplified by the NRC/ASEB study report on NASA's roles in technology vis-a-vis the commercial, industrial, and military space user needs. We, therefore, see no need for such an analogous initiative.

b. Coordination with other agencies, the private sector, and academia occurs at both informal and formal levels. Extensive interaction occurs through exchanges at symposia, workshops, and professional society meetings. Furthermore, formal committee mechanisms exist for oversight and guidance on interdependent technology efforts with other agencies such as the DOD, Air Force, FAA, and DOE. The

private sector interacts extensively through the NASA Advisory Committees of which space systems technology is an important element. NASA participates in the formal DOD managed reviews of aerospace industry IR&D programs as well as through interactions at a more detailed level on a continuing basis.

QUESTION A-15:

Ten-Year Plan

For several years, the Congress and industry have complained about NASA's lack of a comprehensive long-range plan. Now that NASA's next major technological effort has been approved by the President, why would it not make sense for NASA to now develop an integrated ten-year plan that specifies the Agency's recommended programs and activities (at some assumed baseline level of budgetary support), along with options regarding what could be added or would have to be deleted if the baseline budget were increased or decreased by 10 to 20 percent?

ANSWER A-15:

During 1982 and early 1983, NASA prepared a long-range plan, documented it in a planning report, and made that report available to the Congress and other organizations and individuals. Although the title of that report is "NASA Program Plan Fiscal Years 1984 through 1988," its contents include a considerable amount of planning information extending out to ten years and, especially in the areas of space flight and space science, several years beyond. Likewise, the guidance we followed for our planning during 1983 stated specifically that the planning horizon should be ten years, with projections beyond that, if possible and useful. The report, describing the resulting program plan for FY 1985 and beyond, is in process and will be available in the spring. The President's charge to NASA to develop a Space Station can be expected to result in changes in that program plan as we crystallize the ideas and concepts we have been considering. Those changes will be reflected in our planning for FY 1986 and beyond, which currently is getting under way.

QUESTION A-16:

In a recent GAO report entitled, Implications of NASA/DOD Participation in Space Shuttle Operations, it was estimated that one-third of the FY 1983 Shuttle operation funding was DOD-related. What portion of the FY 1984 and 1985 Shuttle operations budget would you ascribe to DOD or joint

civil/military-related missions?

ANSWER A-16:

The referenced GAO report was published in November, 1983. NASA strongly disagreed with the methodology used by the GAO and in their conclusions. NASA's position is that those items in Shuttle operations relating specifically to DOD requirements are funded by reimbursements from DOD. DOD also provides reimbursements to pay for each DOD flight based on a Memorandum of Agreement between the two agencies.

Thus, in the NASA budget request for Shuttle operations, there are no funds for DOD related missions. In the total funding of Shuttle Operations (that is the total appropriated funds plus reimbursements from other Government, foreign or commercial users), the DOD portions are approximately five percent in FY 1984 and 15 percent in FY 1985.

QUESTION A-17:

We, on the Committee, have recognized the importance of the Orbital Maneuvering Vehicle for the efficient operation of the Shuttle and the Space Station by supporting it in the FY 1984 budget. It is not a new start in FY 1985. Can we assume that it will be a new start in FY 1986?

ANSWER A-17:

With approved FY 1984 funding, we will select at least three contractors to perform a one-year Phase B, or system definition study, in 1984 and 1985. With the results of this effort, the OMV will be considered as a potential new start candidate during our FY 1986 budget deliberations.

QUESTION A-18:

It is understood that OMV is an important element of the planned Space Station, but isn't it needed as soon as possible to extend the capability of the Shuttle?

ANSWER A-18:

The OMV could extend our ability to deliver, observe, retrieve and repair satellites which operate beyond the Shuttle's normal operating envelope. It could allow us to manifest, on a single mission, payloads requiring different altitudes or inclinations. We already have several examples of retrieval, observation or return missions which might have been

conducted had an OMV been available (e.g., HEAO-B retrieval, Landsat, SEASAT).

QUESTION A-19:

If OMV is a new start in FY 1986, when will it be operational?

ANSWER A-19:

It would require a 48-56 month flight development program.

QUESTION A-20:

Does DOD have a number of applications for the OMV?

ANSWER A-20:

DOD is currently assessing their needs for an OMV, but a number of candidate applications would appear possible, particularly in polar orbits.

QUESTION A-21:

Is DOD planning to support the development of OMV? With funds? How much?

ANSWER A-21:

We do not know at this time. Our Phase B contractors have been asked to assess the design, development, schedule and cost impacts to implement special OMV capabilities unique to DOD missions. This initial assessment, to be funded at $.5 million to $1.0 million by DOD, will be a factor in determining the eventual overall level of DOD support.

QUESTION A-22:

How many OMVs will be needed to meet NASA and DOD requirements?

ANSWER A-22:

The potential development program would provide one flight unit with which to conduct flight testing and gain flight experience. The eventual fleet size will be determined by several factors:

- NASA's future STS utilization might require a minimum of three flight units; one based at ETR, one at WTR and one spare in-flow unit.

- In addition to the above, Space Station needs will be determined by mission model studies currently underway.

o DOD requirements will be defined by studies currently underway, as discussed above.

QUESTION A-23:

Can you please describe the current agreements that NASA has with the Defense Department regarding the prices that will be charged for DOD use of the Shuttle.

ANSWER A-23:

The current NASA/DOD agreements on Shuttle use contain the following provisions for prices of DOD launches:

- DOD will pay $16.0 million (FY 1975 dollars) for Materials and Services for all DOD launches in FY 1984 and FY 1985.

- DOD will pay a rate fixed at $29.8 million (FY 1975 dollars) per DOD launch for FY 1986 through FY 1988.

QUESTION A-24:

Do these prices fully cover NASA's incremental or "out of pocket" costs for operating the Shuttle?

ANSWER A-24:

The price charged to DOD for the materials and services (SRB, ET, orbiter hardware, crew equipment, main engine, and contract administration) for launches in FY 1986 through 1988 is the estimated cost of these elements in that time period. Because the FY 1984 and FY 1985 price was not sufficient to cover these costs, the price was changed as just described.

QUESTION A-25:

Will DOD be charged higher fees when one of their launches requires the use of a non reusable filament wound solid rocket booster cast (which will be substantially more expensive than refurbishing and reusing a steel-cased booster)? If not, will NASA lose money on such flights (i.e., will the flight cost more than DOD pays)?

ANSWER A-25:

Because the added performance is part of a capability commitment made by NASA, DOD is not being charged an additional amount for using the filament wound case (FWC) SRB's on their flights.

The FWC boosters are manifested as needed by NASA to meet baseline NASA performance commitments for STS missions. While DOD mission requirements fall within these NASA performance commitments, not all DOD missions require the FWC boosters. On those which do, the DOD flight charge will reflect the costs of materials and services if the FWC boosters are reusable.

QUESTION A-26:

In your view, are these pricing policies fair to NASA? If not, how should they be changed?

ANSWER A-26:

The pricing policies provide the framework and conditions for appropriate reimbursements by DOD for STS flight charges. They were developed in recognition of the major investment the DOD is making in the STS program.

QUESTION A-27:

Are there still some elements of the STS that are not adequately funded or facilitized to reach a flight rate of 24 launches per year? If so, what are they? What is being done to correct this situation?

ANSWER A-27:

JSC current capability is budgeted to support at least 24 flights per year. However, recent experience in Shuttle Training Aircraft (STA) training shows that a fourth STA may be required due to the need for more crew training than previously believed necessary.

At KSC sufficient capability currently is 20 flights per year for Shuttle processing. Payload processing capability is affected by the mix and scheduling of payloads and there may be some deficiencies in this area.

The capability to support a flight rate of 24 per year currently does not exist for the External Tank and Solid Rocket Booster projects. However, planning and funding requests are in place to ensure the capability to support a flight rate of 24 per year by FY 1989.

QUESTION A-28:

Are you satisfied that the Space Shuttle will be able to provide the lift capability required by heavy DOD

payloads in sufficient time to meet the scheduled launch dates for those payloads? If not what is being done to correct the problem?

ANSWER A-28:

Yes, we are satisfied that we can provide the lift capability consistent with our time-phased commitments to the DOD. Possible performance improvements and enhancements were studied and we are now embarked on a course to implement selected items in a timely manner.

Items that are currently planned or are underway are: main engine certification to 109 percent power level, development of filament wound case SRBs, incorporation of lightweight SRB nozzles, consumables loading optimization, and propellant reserve reduction.

QUESTION A-29:

We all realize the critical importance of maintaining a robust supply of spare and repair parts if the Shuttle is to support the manifest without major delays. Could you explain what NASA is doing to ensure that an adequate supply of reasonably priced spares will be available when needed?

ANSWER A-29:

Spares and repair parts availability is a critical element in Shuttle operations. As the operation of the Shuttle system matures, NASA's ability to identify the spares and repair parts inventory levels will improve as more data is accumulated. This developing data base is also permitting us to optimize our spares and repair part systems including costs.

NASA's spares and repair parts procurement approach is divided into the following phases:

- 1981-1983 - Start-ups and production assets as major source
- 1982-1986 - Initial lay-in; at least one of each LRU (Line Replaceable Unit) to achieve 12-16 flights/year
- 1985-1987 - Rate build-up; Increase LRU's to support 24 flights per year
- 1983- Replenishment of spares and repair parts as they are used up to assure availability

Our budget for spares and repair parts has been laid out to support this plan. To assure that the price paid for spares and repair parts is minimized, NASA utilizes a number of approaches including the following:

o procuring spares as part of an ongoing production buy rather than a separate spares buy;

o combining buys for common parts used on different Shuttle systems;

o purchasing items through GSA stock, whenever possible, rather than incorporating a unique design requiring special order;

o procuring parts for life of the program where a vendor has indicated that production will be discontinued; and

o procuring directly versus through a contractor.

In addition, NASA reviews and approves the recommended spares buy lists submitted by its contractors. These detailed reviews include the contractor's basis for quantities recommended as well as vendor quotes. NASA recognizes that as the Shuttle increases in flight rates and achieves mature operations that cost-effective and reliable logistics support to the Shuttle will be a significant factor in achieving flight rate and schedules at a competitive cost.

QUESTION A-30:

NASA seems to be in the mode of recompeting all aspects of the STS program. Does it really make sense to recompete the contract for a company that is performing above specification, ahead of schedule, and below cost?

ANSWER A-30:

The possibility of recompetition has always been an integral part of our long range procurement strategy on all of our contracts. We do not want to make long term commitments that could preclude our achieving even greater savings through creative and innovative techniques/processes and cost applications. If we find through studies that savings could be gained without degradation of performance, while maintaining reliability and safety, we would want to pursue those possibilities.

QUESTION A-31:

If not, what standards do you think should be set to guide the Agency in determining when it is appropriate to recompete contracts?

ANSWER A-31:

The size of the job in terms of its scope and proposed length in time should be sufficient enough to make recompetition worthwhile. The timing of recompetition is of importance. It should be introduced when the configuration is set and the majority of the development activity has been accomplished and costs of transition could be minimized. Planned production rates should also be somewhat stabilized, so that investment costs can be accurately sized by the prospective competitors especially for such things as facilities, tooling, and qualification of manufacturing processes. The capability and performance of the incumbent contractor would be significant determinants in any competition evaluation.

QUESTION A-32:

Please summarize the current status of NASA's efforts to commercialize expendable launch vehicles?

ANSWER A-32:

Three companies submitted proposals to commercialize NASA's Expendable Delta and Atlas Centaur launch vehicle systems. General Dynamics Convair (GDC) proposed to take over the Atlas Centaur. Transpace Carriers proposed to take over the Delta vehicle system, and the Cyprus Corporation proposed to utilize some Delta vehicle material and tooling to produce a commercial upper stage they are considering offering to STS customers.

The current status of actions taken consist of the General Dynamics Corvair being selected for operation of the Atlas Centaur program and information is being exchanged between NASA and GDC prior to negotiations. A draft agreement has been forwarded to GDC, and a response with initial negotiations is anticipated in early March, 1984.

We have notified Transpace Carrier, Inc. (TCI) of our willingness to negotiate with TCI leading to a commercialization agreement for the Delta vehicle system. Information has been exchanged with TCI and negotiations have begun.

In the case of the Cyprus Corporation regarding access to certain Delta production equipment to be used to modify a second stage of Delta as an upper stage with the Shuttle, steps are being taken by NASA to provide this access.

NASA is being fully responsive to the President's directive, including participation and coordination with the Department of Transportation (DOT) selected as the lead agency within the U.S. Government to serve as the focal point for all inquiries and activities relative to commercial ELV activities.

QUESTION A-33:

What will be NASA's policy regarding the charges to be assessed to ELV operators who use Government launch or tracking facilities--will they be charged "incremental, additive cost" or some higher level of pricing?

ANSWER A-33:

Charges to commercial operators of NASA Expendable Launch Vehicles will be assessed at least two ways. First, use of Government tooling and equipment will be provided to the commercial operator for a use fee and a commitment to maintain, repair, and replace tooling and equipment used. Secondly, support such as tracking and range support will be charged on an additive cost basis.

QUESTION A-34:

How does ELV commercialization interact with a decision on a fifth orbiter?

ANSWER A-34:

We anticipate no interaction between commercialization for expendable launch vehicle enterprises with a decision on a fifth orbiter.

QUESTION A-35:

In your view, why is DOD now moving to reverse its earlier decision regarding the availability and use of ELV's?

ANSWER A-35:

DOD is not reversing its earlier decisions, but considering their options within the Presidents 1982 space policy . DOD has told us that they must ensure the availability of an adequate launch capability to provide access to space at all levels of conflict.

The Honorable Edward C. Aldridge, Jr., Under Secretary of the Air Force, addressed this question in his February 23, 1984, statement before the Committee on Science and Technology, Subcommittee on Space Science and Applications, House of Representatives.

QUESTION A-36:

What are your opinions regarding this trend and its implications?

ANSWER A-36:

The National Academy of Engineering is presently examining the various options available for use of ELV's. Presentations by NASA and the DOD have been made on the studies concerning both Shuttle-derived launch vehicles and modified existing expendable launch vehicles.

We believe the Shuttle, with its built-in redundancy, the ability to examine (except for the external tank) all components after each flight, and the added information provided by the crews, make it the most reliable and flexible launch vehicle ever available to the United States.

If provision for an ELV capability for national security is to be made, then we believe that a thorough analysis should be made of a potential Shuttle-derived launch vehicle. There are some attractive features of such a potential vehicle such as it could take advantage of more recent technology; and permit the use of some of the same spares, launch facilities, and manpower.

QUESTION A-37:

In a November 17, 1983, report to NASA, the NASA Advisory Council recommended that until the Shuttle is fully operational the Agency should continue to use or have available some Delta-class launch vehicles in order to:

- Assure commercial customers that their payloads would be able to get into orbit in the event that the Shuttle experiences a major delay.

- Provide a surge capability for periods when launch demands exceed available Shuttle capacity.

- Provide an option to tying up a dedicated Shuttle in order to orbit a small "Landsat" or weather satellite from Vandenberg.

What is NASA's position on this recommendation?

ANSWER A-37:

As the Shuttle matures operationally, NASA is continuing to provide an ELV capability on a fully reimbursable basis. Delta launch vehicle production is planned through 1984 for launches through mid-1986, and there will be available two completed Delta vehicles along with residual Delta hardware for three additional vehicles. Atlas Centaur production is planned through 1985 for launches through mid-1987. In addition, the USAF Atlas Vehicle will support DOD/NASA launches from Vandenberg AFB.

In addition to NASA's continued role in providing an ELV capability, NASA is currently negotiating agreements with General Dynamics Convair and Transpace Carriers, Inc., who have been recently selected in open competition to be sole operators of the commercial Atlas Centaur and the Delta launch vehicle.

QUESTION 38:

What is your best estimate of when the next TDRS will be launched?

ANSWER 38:

Our best estimate of the launch date of TDRS-B is early 1985 as reflected in recent discussion with the USAF on the status of the Inertial Upper Stage.

QUESTION 39:

What is being done to ensure that it will not experience the launch and operating failures sustained by the first TDRS?

ANSWER 39:

With regard to launch failure, the USAF has completed a comprehensive failure review on the IUS upper stage, identified probable failure modes, undertaken redesign and remanufacture activities, and will follow these steps with a retest program to ensure vehicle readiness prior to the next launch.

With regard to spacecraft failures, we have already undertaken corrective actions on some problems and are continuing to investigate those more recently encountered. Modifications have been made to thruster housings to provide a more stable thermal environment. Revised manufacturing and inspection procedures are being utilized on the K-band diplexers. The K-band Traveling Wave Tube Amplifiers

(TWTAs) are undergoing intensive factory testing while design modifications are being considered. These actions provide confidence that the experiences of the first spacecraft will not recur.

QUESTION A-40:

This country is the world's leader in space. If properly utilized, our space capabilities could likely improve the quality of life in third world countries and among their people. However, it is our understanding that generally when third world countries ask for support from NASA they are turned down. (In other words, we are not talking about cooperative programs between equals, but programs in which NASA would have to provide some aid.) Further, it is our understanding that no agency of government in this country has given a comprehensive look into if, and to what extent, our space capabilities could be used as an effective foreign policy tool among third world nations. Why has such a study not been conducted?

ANSWER A-40:

Since the beginning of the U.S. Space Program, the application of space research for the benefit of national and international communities has been a major objective of U.S. Government agencies. To carry out this goal, the United States encourages international activities open to involvement of foreign space agencies, academic organizations, and individuals. Each U.S. Government agency conducts its programs in a different manner and brings to its collaborative efforts varying financial resources. For NASA, projects are structured such that NASA and its foreign partners are responsible for the necessary budgetary and intellectual resources to carry out jointly agreed upon roles when mutually beneficial scientific objectives can be achieved. While NASA, as an R&D Agency, has no specific budget for international cooperation, we look for international cooperation in our programs where it is mutually beneficial.

Question 41:

You have recently received the Commercialization Task Force's draft report.

a. What do you plan to do in response?

b. Aside from initiatives related to Shuttle marketing, what role can NASA plan to enhance the commercial aspects of space?

Answer 41:

a. I am considering a NASA policy on space commercialization and, when determined, will direct NASA managers to implement this policy.

b. NASA can reduce the technical, financial and institutional risks associated with doing business in space.

To reduce technical risks, NASA is considering the following:

Support selected research aimed at commercial applications; ease access to NASA experimental facilities; expand the availability of space technology information of commercial interest; and encourage the development of facilities necessary for commercial uses of space.

To reduce financial risks, NASA is considering the following:

Continue to offer reduced-rate space transportation for research and development space endeavors; assist in integrating commercial equipment with the Shuttle; provide assistance, where appropriate to stimulate commercial space ventures; and, under certain circumstances, purchase commercial space products and services.

To reduce institutional risks, NASA will:

Speed integration of commercial payloads into the orbiter; shorten proposal evaluation time for NASA/private sector joint endeavor proposals; establish procedures to encourage development of space hardware and services with private capital instead of Government funds; and, introduce new institutional approaches for strengthening NASA's support of private investment in space.

QUESTION A-42:

It is clear that the Space Shuttle development has had a major adverse impact on the health of the space sciences within NASA. With the prospect of a major Space Station developmental effort, how can we place the proper "fence" between Shuttle operations and space transportation development projects and this essential research base?

ANSWER A-42:

The requirements of the Shuttle program were given a very high priority in overall Agency planning, but our analysis does not indicate that the impact on space science was major or adverse. In fact, the Space Science and Applications funding has constituted approximately 20 percent of the total NASA research and development funding level over the last eight years (in 1982 constant dollars). The recent success of Spacelab 1 demonstrates the potential of the Space Shuttle for space science. With regard to the Space Station, the Agency is structuring a program which will maintain a proper balance between the station and the payloads.

QUESTION A-43:

In the area of international cooperation on space projects, historically NASA has found it necessary to begin negotiations with other countries prior to full program authorization and approval. Program deferrals or cancellations have often resulted in ill will. What mechanisms can you envision which would allow such negotiations to take place in good faith without the prospect of such cancellations?

ANSWER A-43:

Typically, NASA negotiations with a foreign cooperative partner begin before a new start approval. These negotiations are necessary in order to have a good preliminary understanding of the nature and size of foreign participation in the proposed project for which NASA might request approval. NASA is careful to ensure that its prospective partner understands that the planned project is not yet approved, and that the efforts of both sides during this phase are based on intentions, and best efforts and not on specific new start approvals. The specific commitment to another country is made through the signature of a cooperative project agreement, which comes after NASA has obtained a new start approval and appropriation of required funds by Congress. Even then, all of NASA's cooperative agreements are subject to appropriation of funds for each respective fiscal year. Throughout the project, NASA seeks to consult as closely as possible with its partners to keep them fully informed, and thus minimize the negative impact on long range cooperation, in case a deferral or cancellation becomes necessary.

Although unlikely for a variety of reasons, one mechanism that can be envisioned that would greatly reduce the potential for cancellation of an agreed

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international cooperative project would be prior multi-year authorization by Congress for the cooperative partners currently obtain such multi-year authorizations. However, they also understand that such a mechanism is not easily obtainable under our Authorization and Appropriation system and agree to proceed with a project with the clear knowledge that NASA's commitments are subject to obtaining authorization and appropriation of required funds for each respective fiscal year.

QUESTION A-44:

During our July, 1983, hearings on NASA's Five Year Plan, the Office of Space Science and Applications projected an increasing budget through 1989 characterized primarily by new starts of up to a billion dollars in the aggregate.

a. Where do you see the emphasis in these new starts being placed (i.e., flight projects, data analysis, or research base)?

b. The resource allocation between planetary exploration, physics and astronomy, and earth sciences is projected to remain relatively constant. Does this represent what you consider to be the optimum allocation of resources?

ANSWER A-44:

a. Space Science and Applications planning is an element of the overall integrated effort to develop and execute a balanced and forward looking program. The five year planning document does, in fact, emphasize potential new flight projects; however, these flight projects will evolve from a strong research and analysis program. The flight project mission operations and data analysis, in turn, provides new information on which to base additional research. The research and analysis, the flight projects, and the mission operations and data analysis are interdependent and mutually supportive. While the planning document focuses on flight projects, the budget process ensures the proper program balance. We will continue to ensure that there is a proper balance among all the activities required to carry out a successful program.

b. The allocation of resources to conduct specific approved missions during the period covered by the five year plan will be based on the funding requirements of the respective missions and not on a set allocation to a specific budget line item or discipline.

Question 45:

The NASA University Relations Study Group, in their 1983 report, recommended a modest augmentation to the 1985 budget for graduate fellowships, university laboratory instrumentation and capital equipment, and increased data analysis activity.

a. Exactly what funding increment did they recommend?

b. Although you as Administrator commissioned the study, it does not appear that these recommendations have been followed in the budget. Is there funding as recommended? If not, why not?

Answer 45:

The NASA University Relations Study Group recommended $10 million annually for equipment grants, $20 million for data analysis and establishment of a NASA graduate student study program as well as continuing studies on the relations between the NASA centers and the universities and how to do science on the Space Shuttle in a more cost effective manner. The FY 1985 budget request does include an increase of funding for data analysis. In addition some new university instrumentation will be purchased with some of the requested research and analysis funding which will go to educational institutions. It is recognized that the proposed additional funding in this area is highly desirable and we expect it will again be a FY 1986 budget issue within the Agency. We have an ongoing graduate fellowship program between the universities and the NASA centers; however, we are studying ways to extend this program in accordance with the recommendations of the NASA University Relations Study Group.

QUESTION A-46:

Last year (FY 1984), the Congress augmented the Planetary/Research and Analysis budget. This year, you have reduced the number below the 1984 budget. Why? What activities will be cut?

ANSWER A-46:

The requested level in this area reflects the difficult balance that NASA has sought to achieve in the planetary exploration program between mission activity and supporting research. Both are equally essential to the overall program. The intent of the Solar System Exploration Committee was to provide more flight opportunities to the Planetary Exploration community. NASA has responded by

requesting the initiation of the Mars Geoscience/Climatology Orbiter in FY 1985; thus, the total Planetary Exploration request reflects a significant increase from FY 1984 to FY 1985.

QUESTION A-47:

The Solar System Exploration Committee (SSEC) recommended that NASA begin a program of "Planetary Observers" analogous to the "Explorer" line in Physics and Astronomy. The program does not seem to be in the budget. Why not? The Planetary Observer mission recommended by the SSEC the Mars Geoscience/Climatology Orbiter, is in the budget, but the Planetary Observer program is not. The main point of the SSEC program was the need for stability that would be provided by such a program. How do you purpose to obtain this stability in the program if you don't have this program to keep a series of inexpensive flight missions in the pipeline?

ANSWER A-47:

The highest priority Planetary Observer mission recommended by the Solar System Exploration Committee (SSEC) was the Mars Geoscience/Climatology Orbiter (MGCO) which is a part of NASA's FY 1985 budget request. The major point of the SSEC recommendation was to provide more stability within the Planetary Exploration community by providing more flight opportunities. Therefore, with the development start of the Venus Radar Mapper Mission in FY 1984 and initiation of MGCO in FY 1985, we believe we are providing more flight opportunities to the Planetary Exploration community. We are, of course, continuing to define potential future relatively low-cost Planetary Exploration missions consistent with the SSEC recommendations.

QUESTION A-48:

What are NASA's plans in 1985 for the following missions that have been for a long time?

a. AXAF
b. SIRTF
c. SOT
d. TOPEX
e. NROSS

ANSWER A-48:

a. NASA is currently in the process of selecting Phase B contractors for AXAF definition. These studies will be conducted over a period of approximately two years. Therefore, the earliest

that NASA would be in a position to propose AXAF as a new start is FY 1987.

b. Definition of the Shuttle Infrared Telescope Facilities (SIRTF) is much further behind AXAF. NASA is currently considering two potential SIRTF concepts: a Shuttle attached payload and a free-flyer mode. Therefore, a decision on the SIRTF concept which might be pursued will not be made for several months.

c. The Solar Optical Telescope (SOT) is currently proceeding through the definition phase; our current funding plan in FY 1985 assumes that pre-development activities will be continued.

d. In FY 1985, we plan to conduct Phase B studies on both a joint U.S./French cooperative mission and on a U.S. only mission.

e. NASA currently plans to provide a scatterometer (NSCATT) to the U.S. Navy for flight on their proposed N-ROSS satellite. The scatterometer is included in our FY 1985 budget request at a level of $15 million.

QUESTION A-49:

You recently stated that NASA intends to "rescue" the failed Landsat-4 satellite.

a. When would this occur?

b. With respect to timing, how does this fit with the expected life of the Landsat-5 (to be launched March 1, 1984)?

c. How does this fit with the Administration decision to commercialize land remote sensing?

ANSWER A-49:

a. Retrieval of Landsat-4 cannot occur until a polar orbit Shuttle mission capability is available from the Western Space and Missile Center, Vandenberg AFB in 1986. Landsat-4 will be deboosted to a Shuttle retrievable orbit if the spacecraft exhibits additional solar panel degradation; otherwise Landsat-4 will continue to collect data.

b. The expected lifetime of Landsat-5 based on design is three years. The retrieval of Landsat-4 would be timed to occur while Landsat-5 is still operating.

c. There is no conflict with the Administration's decision to commercialize land remote sensing. When Landsat-4 is removed from service, its ownership reverts back to NASA. NASA is studying the advantages of a repair mission in-orbit versus retrieving and returning the spacecraft to earth. Whether there are private sector interests in a Landsat-4 retrieval/repair mission for commercial opportunity is not presently known. However, the present inter-agency agreement between NASA and NOAA returns responsibility for Landsat-4 to NASA upon removal of this spacecraft from service.

QUESTION A-50:

It is clear that science should play a major role in the design and utilization of the Space Station.

How can you assure us that the development of related science projects proceeds at a vigorous pace in order to take optimum advantage of the station?

ANSWER A-50:

I agree that the Space Station will indeed play a major role in the conduct of future science initiatives. Based on this expectation, I have formed a committee under Dr. Peter M. Banks of Stanford University to evaluate the potential of a Space Station in performing specific science endeavors. Ultimately, the ability to make use of the Space Station will be driven by the capability of the Space Station to accommodate such science at a reasonable cost to the user over the next two years, we will identify the resources available for Space Station science, and plans to move currently planned science to the Space Station.

QUESTION A-51:

Recently, Hughes Galaxy filed an application with the FCC for the operation of a two satellite K-band communications system.

a. Do you believe the Hughes system will be substantially different that the original goals for the NASA ACTS program?

b. Does the Hughes proposal not suggest that in general the private sector is most appropriate for pursuing such communications R&D?

c. What role, if any, should NASA play? That is, in the area of satellite communications, should NASA have a flight program to demonstrate advanced technologies?

ANSWER A-51:

a. A comparison of the Hughes filing and the ACTS flight program (RCA proposal) are attached (Tables A-E).

b. The Hughes filing is for an operational system which will utilize less risky technology than the ACTS flight program previously assumed.

c. NASA should continue to work with the U.S. industry to jointly identify technology development needs. NASA should then concentrate on the development of long-term high-risk technology and allow industry to concentrate on the nearer-term operational requirements.

QUESTION A-52:

Mission of NASA Study

In October, 1983, the NASA Advisory Council released its recommendations from its study on the "Mission of NASA."

a. What is the current status of the study?

b. Have you formulated a formal response to the Advisory Council's recommendations?

ANSWER A-52:

a. The study was completed and submitted to NASA in October, 1983.

b. A formal response to the Council's recommendations is being prepared.

QUESTION A-53:

Regarding the recommendations from the "Mission of NASA Study":

a. The Council has recommended that a new office, within NASA, be created, "fenced" apart from other NASA activities, to focus on Shuttle operations and utilization. Is NASA considering such a change?

b. The Council has recommended a stepped-up program in the space sciences, involving exploration of the solar system and enhanced activity in the earth sciences. These recommendations go beyond the core program recommended by the Solar System Exploration Committee (SSEC). Can you tell us about NASA's plans, including budgetary, in this area?

ANSWER A-53:

a. Note that the Council's recommendation was to create that new organization "at the appropriate time..." We have taken a number of steps toward this and expect to continue to move in this direction. We do not believe, however, that a totally separate organization is appropriate at this time, Our new budget structure, which separates Shuttle production, operations and other supporting space activities from the R&D budget, is a step in the direction of "fenced" resources recommended by the Council. At a later date, such separation may well be desirable and would receive serious consideration.

b. NASA's planning, both in solar system exploration beyond the SSEC's core program and in studies of the Earth, is not yet sufficiently far along to describe in terms of specific missions, schedules, and budgets. In fact, additional studies by the SSEC and a study of Earth science programs by a new group, the Earth Systems Science Committee (both under NASA Advisory Council auspices) are expected to provide recommendations that will guide planning in both areas. When the results of those studies are available, NASA will be able to evaluate the respective recommendations and incorporate them appropriately in its planning.

QUESTION A-54:

What steps has NASA taken, or will it take, to improve coordination with the NSF in the space science area? Would NASA's effectiveness in carrying out its space science missions be enhanced by a "lead agency" designation for space science?

ANSWER A-54:

Over the years, in carrying out its space science program, NASA has had close coordination with the National Science Foundation (NSF). For example, there are regularly scheduled coordination meetings between the Office of Space Science and Applications staff and the staff of the various divisions in the Directorate for Astronomical, Atmospheric, Earth, and Ocean Sciences at NSF. Even more important are the frequent individual contacts between the staff at both agencies who are responsible for various areas of the program. We believe there is an excellent working relationship between NASA and NSF, and the most important step to be taken is to make sure that the existing relationship is maintained.

QUESTION A-55:

The Council has recommended that NASA take greater steps to enhance awareness within Government of the value of aerospace programs as an instrument of U.S. foreign policy.

a. How would you characterize NASA's current role and influence in foreign policy? Is it adequate? If not, how might it be improved?

b. What steps, if any, is NASA taking to increase awareness of aerospace programs as instruments of foreign policy?

ANSWER A-55:

In response to the statutory mandate that NASA conduct its activities "so as to contribute materially to...cooperation by the United States with other nations," most of NASA's programs, since its inception, have had some form of international involvement. While NASA has no specific budget for international cooperation, we look for international cooperation in our programs where it is mutually beneficial. NASA has also worked closely with the White House and the State Department over the past several years to demonstrate the value of international participation in our programs to U.S. foreign policy goals. As a result, the perception that aerospace programs are valuable as instruments of U.S. foreign policy is becoming more widely recognized. This was most recently demonstrated by the inclusion, in the President's State of the Union Address, of international participation in the Space Station as one of its primary elements in order "to strengthen peace, build prosperity, and expand freedom for all who share our goals." In the final analysis, however, it remains the responsibility of the Department of State to formulate foreign policy. NASA's responsibility is to recommend areas in which space activity can contribute to that foreign policy.

QUESTION A-56:

Last October, in its report on the mission of NASA, the NASA Advisory Council recommended that NASA adopt as co-equal objectives (in terms of management thrust and attention, but not funding levels) the pursuit of manned technology programs and the exploration of the solar system. What is NASA's position on this recommendation?

ANSWER A-56:

In its study of the "Mission of NASA," the NASA Advisory Council offered a number of recommendations with regard to NASA's space mission. Specific recommendations were offered for solar system exploration, fundamental scientific research, space technology development, and expansion of the human presence in space. We believe that NASA is being responsive to all of recommendations regarding the pursuit of manned technology programs and the exploration of the solar system, both are indeed co-equal objectives. NASA is continuing a vigorous program of solar system exploration with the request for the Mars Geoscience/Climatology Orbiter new start. In addition, NASA's FY 1985 budget request includes funding for a Space Station which will require increased attention to the development of manned technology capabilities.

Mr. VOLKMER. Thank you very much, Mr. Beggs. Yes, I am sure the subcommittee does have some questions, and I would like to start off with one.

In the first place, I don't want to make the hearing solely on the space station. We will try to get other things, but that has the greatest amount of publicity, and I am sure a lot of people are interested in it.

In regard to the space station and some of the concerns, there have been those that have expressed in the past concern regarding the remainder of the budget, the impact of a large item as was the shuttle, and now with the space station, how that will impact on other programs. How do you address that question, especially on science programs or planetary programs?

Mr. BEGGS. Well, the science—I think we are both very pleased and proud to report that the science and applications program of the Agency—and when I say applications, that to a large extent is science as well—has received the largest increases in each of the last 3 years—that is, the largest percentage increases—in each of the last 3 years.

We are proud that we are able to bring to you a recommendation to initiate two new starts in the science and planetary exploration arena this year in the upper atmosphere satellite and then the Mars, so-called MGCO. I don't know how we are going to pronounce that one. But they are initiatives which we feel are both very important and ones we have wanted to initiate for some time now, and in the case of the planetary program, it is, I believe, a new and important thrust for the future, because, as I mentioned in my statement, the academies have been urging us to initiate a planetary program where we could fly more frequently than we have in the past, and to address some of the questions, some of the scientific questions, which have been raised as a result of our probes which have been flying over the last 10 to 20 years. Both of those programs, we think, are very important and represent a very important initiative for the long-term future of the Agency.

If I might make this final statement, Mr. Chairman, we are not going to shortchange the science program for a space station. Quite the contrary; we need a strong and vigorous science program in order to make that space station fully operational and capable. Unless we have that, the space station will not realize the vision and the dreams that we have for it.

Mr. VOLKMER. I appreciate those comments, and I hope they will allay some fears of those who see a possible diminution in the efforts in regard to the science planetary programs because of the space station.

I, too, wish to echo your statement. As far as I am concerned, they will not diminish, either, as a result of the effort as far as the space station is concerned.

In relation to that, also, there have been comments by some in the science community that they do not need, or the space station really will not assist in the scientific field as far as scientific research and planetary research. How do you address that?

Mr. BEGGS. Well, I would make these comments on that, Mr. Chairman.

All of us here from NASA had the opportunity a couple of weeks ago to look at the tapes and review the results of the first spacelab mission. The one singular fact that came across to all of us in looking at those tapes was the high degree of interaction between the scientists on the ground. There were roughly 150 scientists from all over the world, I think some 14 or 15 different countries who had experiments of one type or the other on board spacelab-1.

There was intensive interaction, and we still haven't got the TDRS fully operational, as you know; we have one-half of it up there. So we were in contact with the laboratory about 50 minutes on every orbit. But during that 50 minutes, there was intensive interaction between the scientists and the astronauts, and they were both modifying, changing, and improving the way in which the experiments were conducted.

One other thing came out of the spacelab mission which I think is extremely important, and that is that several of the experiments, in one way or the other, failed on orbit; that is, they malfunctioned either in a minor way or, in some cases, a major way, and we were able to repair those—that is, the astronauts were able to repair those experiments—in real time on orbit and put them back in operation so that we did not lose a relatively very expensive opportunity to realize the scientific results from the experiments. I think once the science community realizes the value of that interaction and the value of being able to keep experiments operational for long durations—because, as we proceed toward space station, we are talking about experiments which may run for years—that they will be very enthusiastic about the possibility.

Now, as I mentioned, we are looking at a concept of a space station both of individuals inhabiting a central core and of unmanned platforms where there are instruments that you don't want to have in close proximity to the men and women, so that they can fly, if you will, in formation with the station. When they need servicing, repair, a changeout of consumables, we will be able to do that from the station. I think that is still another great advantage that the scientists will begin to appreciate.

Finally, I would mention that the report that was submitted to us on the study that the Academy did on the subject of space station last year, while it did say that the committee could not recommend support of a space station on scientific grounds alone, it did say that given the initiation of a space station for any of a number of different reasons, they would without question use it. I think the committee might well consider calling Dr. Donahue and some of his colleagues who reviewed the program at that time to appear and give their testimony on that subject.

Mr. VOLKMER. Thank you. I am sure that we will be looking into that area and bring Dr. Donahue and Dr. Banks—you named him, also—in on it.

Mr. BEGGS. Yes, sir.

Mr. VOLKMER. In regard to the space station and our continuing efforts, as I think I have stated in the past, I quite agree that we need to start now on a space station. My question to you is, because of other concerns, not necessarily my own but other things that may arise, what impact—I know that we have $150 million in the

budget for the studies and design—what impact would it be if that were reduced down to, let's say, $100 million from $150 million?

Mr. BEGGS. Well, it would have a severe impact on schedule, primarily. As I have testified to this committee before, the efforts we are initiating on space station can be cut to fit the claw, but we do have a full program for that $150 million.

I would appreciate it if the committee would give consideration to the schedule we will give to you. Mr. Culbertson, Mr. Hodge and others have a fuller explanation of how we plan to spend that money, and I think we can convince you that we have a good program to spend that money.

Mr. VOLKMER. We can address that further tomorrow, then, when we have them up before the committee.

The other area in regard to the space station is, we all hope, I am sure, for international cooperative development. My question is, in the context of the current international competition which we have with ELV's, et cetera, how to draw the other countries, whether Japan or CESA or individual countries in Europe, how are we going to draw them into the actual design and/or construction of the space station or participation in the space station?

Mr. BEGGS. We have not fully outlined that, although we have had extensive discussions with the Europeans and the Canadians and some discussion with the Japanese about the way in which we would proceed to do that. They, of course, are very interested in getting in on as much of the new technology as they can; obviously, that is what everyone wants. Without question, if we want them to participate fully in it, we are going to have to work out a way to divide the job so that they get something for their money. We will have to be the system managers, of course, and we will have to do the job of planning the technology development and planning the way in which the system is configured. But, what we plan to do is work very closely with the Europeans, the Canadians, and the Japanese for the next year and a half as we go through this program definition phase, and by the end of that time, we feel we will be able to assign tasks that will be both reasonable and pleasing to our partners, and we think we can put together a major collaboration.

As you know, Mr. Chairman, the Europeans spent $1 billion for the spacelab as a shuttle complement, and the Canadians spent several hundred millions on the arm. Those contributions were much appreciated, and while some have said that maybe we gave away too much technology. My view is that it was a good horse trade and that they got substantial benefit. There are some Europeans who don't think they got as much for their money as they would have liked; there are others who were very pleased, and I think the majority are very pleased.

I think the same will be true in the case of the station. We will have to do quite a bit of negotiation and trading. But to the extent that we collaborate—and certainly there is not too much money around the world, in all of our budgets, to do the kinds of things that we are planning to do in the next couple of decades in space—to the extent that we can attract their resources to our visions and our dreams, we will not compete; we will collaborate. I think that is an advantage for the United States. I also think it is an advan-

tage for them because in collaborating their money will go further, and that is the reason they will participate.

Mr. VOLKMER. Thank you very much. I will have additional questions later, but I realize that I have gone past my allotted time, even as Chairman. We will proceed.

I now recognize the gentleman from California, Mr. Lowery.

Mr. LOWERY. Thank you, Mr. Chairman.

Mr. Beggs, I have enjoyed your testimony very much. It is encouraging to see this administration realizes this country stayed ahead of the rest of the world because of our technological superiority. Certainly, NASA's has been the cutting edge of those decisions and the increase in Budget is appreciated.

I have questions in about four areas: the space station, fifth orbiter, our policy on ELV's, and the advanced communication technology satellite.

First, what is the priority of the fifth orbiter vis-a-vis a space station?

Mr. BEGGS. I am hesitating here because I want to answer this properly. We consider the completion of our development of the shuttle capability to be the first priority in the Agency, and that will remain the first priority in the Agency for the coming few years.

I mentioned in my testimony we would like to invest some additional money in the main engines, which are the one area that we feel we must improve durability and performance in the future in order to realize the full potential of the shuttle.

We have looked very carefully each year at the question of the fifth orbiter, and except for the desire to have an attrition vehicle, and it is an expensive attrition vehicle to buy, we can find no market demand in the market projections that we have made for the next several years. The one area that probably requires that backup is the area of defense, but we have never had a real positive statement on the part of the Department of Defense that they feel that the fifth orbiter is required. If we could get that and if they would come out strongly for it, I think it might change our view on buying it now.

Now, as you know, we put $400 million in the budget last year—not in the budget last year, but in the run-outs, to buy structural spares. The objective of that was to preserve a minimum production capability once the last orbiter, Atlantis, came off the production line to preserve a warm line. Having done this myself in industry of pulling in your belt and preserving a warm line, I believe that that can be done. For how long? Perhaps 2 or 3 more years, so we have a window of another 2 or 3 years in which to decide whether we want to buy an orbiter or not. It is true that the cost of the orbiter will go up as we advance out in years. We estimated to you that the fifth orbiter a year ago would cost in excess of $1.5 billion. That will move up probably 10 percent or so a year.

Is it then pennywise and pound foolish not to buy it early? I don't think so. Most future decisions are discounted at 10 percent, that is to say, the value of the money is 10 percent. That is what the Treasury is paying in the marketplace for money. So, I think the country can afford to wait as long as you believe that you can

get the orbiter if and when it is required. As I see the program today, I do believe we can get it if and when we require it.

Mr. LOWERY. How does the decision to proceed with a space station and have it completed within a decade impact upon the fifth orbiter decision?

Mr. BEGGS. I don't really think it impacts that decision to a great extent. I mentioned in my testimony the agreement that we have now with the OMB in the out years is that the budget will remain constant in real dollar terms with a growth of perhaps 1 percent. To me, that perhaps is the salient and most important feature in this budget, because in the past we have been running out the program without consideration of the fact that undoubtedly the program was going to continue into the far distant future and that, therefore, you ought to put a wedge in with the expectation that you would spend that money to do new things, augment, upgrade, and so forth. We have that now. At least, it is in the budget for the next 5 years and I think this administration is committed to it. I think the philosophy of that, the fact that we have argued that through in the OMB, I think will remain for some time.

Within those run-outs, I think we could accommodate a fifth orbiter if sometime in the next 2 or 3 years we felt it was necessary. The $400 million we are investing in those structural spares, assuming we use those spares in the construction of a fifth orbiter, will be deductible from the total cost of the orbiter, so we are making an investment, if you will, that contributes to the construction of a fifth orbiter.

I would urge that we continue to watch this in the coming year and that if we feel that the situation has gotten to the point, if we run into a problem with the existing fleet, if we feel we have a significant problem coming up in the future with respect to backup or essential missions such as Department of Defense business, then I think I would definitely come up and recommend to the Congress that we go ahead and initiate the program.

Mr. LOWERY. You commented that a relatively stable NASA budget in the out years—Do you feel it is realistic to build that space station for the $8 to $9 billion that we are hearing about? There are many that suspect that it is going to cost double that.

Mr. BEGGS. Thank you for that question, because I would like to respond to that. Most of the stories that I have read on the station have appeared in the press and in magazines and so forth have bandied about a number of different numbers, and they range everywhere from the $8 billion that NASA has said it will cost for the initial operating capability to maybe $30 or $40 billion through the first decade of the second millenium. They always say, "into the 21st century."

I don't think there is any disagreement between NASA's estimate and those estimates, because we don't expect, and our planning is all based upon the continuation of the NASA program into the 21st century. After the space station reaches its operational capability, we will be putting experiments on it. We will be undoubtedly adding to it and enhancing it, and we will, of course, be thinking about what other things we can do. Since, if you look at that budget, by 1989 we are projecting a NASA budget of something over $9 billion. In the decade of the 1990's, we will be spending in

real year dollars there probably $100 billion. Some large part of that will go to working on and with the space station. So, the difference between the $8 billion initial capability and we stick by that estimate and that estimate, I might add, is done on all the various estimating models, cost models that have been validated by OMB and the NASA model, $8 billion in 1984 dollars. That is a constant dollar estimate, and that amounts to, if you run it out, sometime in the early 1990's, and I hope you don't pin me down for a very specific date today, something over $10 billion in then-year dollars.

Mr. LOWERY. $10 billion?

Mr. BEGGS. In then-year dollars, that is, working your way through the 1980's.

Mr. LOWERY. Over that decade?

Mr. BEGGS. Over that decade period.

Mr. LOWERY. Mr. Chairman, I know my time has run short. Let me just ask one further question.

The decision on commercialization of ELV's, how do you feel that interacts with the decision on the fifth orbiter?

Mr. BEGGS. That is a very complex question. The studies that I have seen by the concerns, private enterprise concerns, which have come to us and proposed to take over those ELV's project much higher markets than NASA studies project. They would suggest that above a 24-per-year shuttle flight rate, that there may be as much as another—almost as much again—some of the more optimistic forecasts and certainly plenty of room to fly payloads on both Delta class or Atlas class launch vehicles.

That is what they are predicated on. They are predicating their investments in the commercial development of those families on the basis that the market will grow to that extent, because they know, and have been told, that the shuttle is going to remain in operation through the coming decade, that the Government has every intent of doing that and that our pricing policy will not change through 1988. It will probably change after 1988, but it will not change through 1988. So, they are making their bet on that premise.

However, the issue is further complicated by the fact that there are other studies going on around town to perhaps develop commercial versions of Titan as well. So, there is a lot of activity here, and how it all adds together, I will tell you I just do not know. It is a very difficult picture to read. My crystal ball is pretty cloudy on that one. I think if someone wants to step up to the table and put his money down and bet that the market will grow to that extent, we certainly ought to let him, in the great American tradition. Would I bet my own money? I think I would look very carefully at it if I were betting my own money.

Mr. LOWERY. Thank you, Mr. Beggs. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you. I now recognize the gentleman from Washington, Mr. Chandler.

Mr. CHANDLER. Thank you, Mr. Chairman.

I, too, was especially interested in the ELV question from a colleague from California. Also with regard to the use of the shuttle, Mr. Beggs, if you could talk about the DOD use of the shuttle, the

pricing policy, how that relates to the out-of-pocket cost and enlighten the committee on that, I would appreciate it.

Mr. BEGGS. Yes, sir. We priced the price of the DOD on exactly the same basis that we price to the commercial customers. We felt that we could not vary our pricing philosophy to the DOD because it would represent a cross subsidy, if you will, from the DOD into the commercial and science sectors if we charged them more. The only thing that we did not charge—we took into account two things. One was the investment that DOD is making on their own in the west coast launch facility and the other pieces and parts that they have contributed, and two, we took out the amount we had put in as a contingency allowance in the commercial price which we don't have in the case of the DOD. Other than that, they are paying the same as the commercial.

How we are doing in terms of recovering our costs at those prices, we think we are doing very well. We are coming down some pretty steep learning curves in the pieces and parts of the program. If you watch us in the next couple months, you will have a good idea of how well we are performing because we are going to bring *Challenger* back from the mission we are launching on Friday, it gets back the 11th, and we are going to turn it around and fly it again early in April which is about 35 working days later.

However, we are not recovering the full cost of flying the Shuttle and we never intended to when you go back and look at the plans that were laid down and given to the Congress back in the early 1970's. What we said was that we would recover the operating costs over a mission model. That mission model, as all mission models do, has changed quite significantly over those years. It is a good deal lower than it was when the projections were made.

Can we then reach break-even at some point in time? I believe we can. When will that come? I think perhaps towards the end of this decade. Whether we will do that will depend on how well we continue to work this system and drive down the costs, bring them down the learning curves, increase the flight rate in a very steady and step-by-step way. If we do, then I think when we submit maybe the fiscal year 1989 or 1990 budget, someone ought to look at that and say is the DOD paying their fair share at that point. If they are not, then something is wrong, but I don't think it is quite appropriate to ask the DOD to pay more at this point in time for their shuttle flights than you are asking the commercial sector or the foreign sector to pay for their flights.

Mr. CHANDLER. Then, in a related way, on the ELV question, the policy that you develop with the commercialization where NASA facilities would be used for the launch of commercial ELV's, how far along are you? What is the policy that you are expecting there?

Mr. BEGGS. Basically, we will lease or in some cases, sell tooling, test equipment, launch facilities, and so forth, at whatever the residual value of that is, or, if you will, we will try to arrive at what is a fair market value of them. Some of them are quite old and, obviously, have been used for most of their economic life. The launch facilities themselves, of course, still have life and still have value.

In charging for the services that we will render, both from the DOD and from NASA—and most of those services will come from

DOD, not from NASA—charging for those services will be done on the basis of incremental cost. That is, the cost incurred above what we are currently spending, which I think is fair both for the Government and for the private operator.

Mr. CHANDLER. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you. The Chair now recognizes the gentleman from Florida, the chairman of the full committee, Mr. Fuqua.

Mr. FUQUA. Thank you, Mr. Chairman.

Mr. Beggs, we are very pleased to have you and the NASA officials here. I think I may have helped you on an acronym for the MGCO. You might use an M and then an "a" and then a "GCO" and get MaGCO. You have some pretty expert people in NASA on acronyms, so I wouldn't want to preempt them from that.

In response to the question Mr. Lowery was propounding earlier as relates to the space station and the fifth orbiter, in the hearings before the subcommittee last year, the Undersecretary of the Air Force testified that they supported the procurement of a fifth orbiter. You indicate that we should keep our options open probably for maybe another 2 years, and I am concerned that at about that time—and I haven't seen the projected budget for the space station—it would appear to me that approximately 2 years, between 2 and 3 years, that it would be on an accelerated increase in budget. If we determined at that point that we needed a procurement of a fifth orbiter, we would have a dual impact on the budget at the same time and really throw the whole NASA budget in an awkward situation, particularly as it related to other programs if we stayed within the overall projected figure of NASA with certain increases. At that time it would probably be upward of $7 or near $8 billion based on the recent growth and also inflation factored in. I am concerned about the impact that that would have on the budget at that time. Could you elaborate on that?

Mr. BEGGS. I will try to. First of all, with respect to the station, we will lay out a schedule and describe very fully—we have some numbers which we have submitted thus far as to how we see the expenditures——

Mr. FUQUA. You were quoted the other day as saying bending metal around 1987, I think.

Mr. BEGGS. Yes, starting to bend metal in 1987.

Mr. FUQUA. I am thinking that at that time the funding buildup would be at a rather rapid increase for that particular program.

Mr. BEGGS. Yes, sir. We are talking about $1 billion or so in 1987 and then perhaps building up to as much as $2 billion at the peak and then coming back down.

Mr. FUQUA. Then that would be around 1988 under the present schedule.

Mr. BEGGS. Well, the $2 billion would be more like 1989, but it would build up to that level and then in the early 1990's start to come down again. However, we have not fully scheduled that program. That is the reason we are going through this phase. I might say at this point that that was our decision. Nobody forced us to do that. We looked at past programs and we decided that it was very prudent in view of the history we have had and in view of the experience we have had both in the Apollo days and in the early shuttle days and in the early days of many of our large programs,

that it would be prudent for us to take a year and a half or more in very closely defining and making sure that we had in mind exactly what we wanted to do before we started.

Mr. FUQUA. I concur fully with that.

Mr. BEGGS. That was our decision. But we haven't fully scheduled what the expenditure will be in the high years, but as we see it, using a level budget in real terms with a growth of 1 percent in the years through 1989, we have a wedge for new initiatives of about $3 billion.

In addition to that, I think that we should take the challenge, that we in NASA should take the challenge, and I have laid this on General Abrahamson and his center directors, that we ought to try to save some money in the operating budget as well as perhaps some of the development budgets, save a little money that would enable us to do some new things in the shuttle program. Among those new things might be a fifth orbiter. However, we think we have room, is what I am saying, if we decide to go forward with a fifth orbiter, and I think that should the DOD—and I know Secretary Aldridge made that statement to the Congress. Unfortunately, the Air Force didn't make it to the OMB. There are two ends to Pennsylvania Avenue and from my point of view they are both very, very important. Unfortunately, when we were in the argument in the OMB, we did not have the support of the Air Force, and that is vital for us, to have that support.

The other thing that I should mention is that we are engaged, and the committee gave us a charge last year to go develop a good marketing plan and we are trying to do that. We are engaged in trying to increase the reimbursible usage of the shuttle to get more customers for it who pay their way. We have been pretty successful. We are doing well. The reimbursements in 1985 are expected to be something over $650 million, and we are going to try to make them grow as time goes on. To the extent that we can make them grow—and we are entering now the new pricing period—the folks who sign up now are paying the higher prices—we can ease the pressure on the appropriations line and the pressure on our budget. That is still another way that we can help ourselves in paying for further improvements to the shuttle including an augmentation of the fleet.

There is another aspect of this, if you will permit me, Mr. Chairman, I would like to touch on. I would like to ask Dr. Mark to comment on it and that is the question that reflects the other part of Mr. Lowery's question which was with regard to the expendables, because sometime in the next several years, if we are going to continue an expendable arm, we are going to think of a new generation of expendables, and we think that we have an option there in deriving those expendables from the shuttle. That will help us as well with the shuttle problem. Do you want to talk to that, Dr. Mark?

Dr. MARK. Yes, sir. Mr. Chairman, I think that is a very important remark because the technology that we have developed in the last 15 years in propulsion as a result of the shuttle program is something that we really should now expand and use for other launch vehicles. We shouldn't really call them expendable anymore because these will be at least partially reusable, that is, we have

built into the technology the element of reusability. We can, for example, with solid rocket boosters alone equal the capability of all expendable launch vehicles that we have today ranging from the Deltas to the heaviest types. By strapping three of these things together, you can, with the appropriate upper stage something of the order of 50,000 to 60,000 pounds in lower Earth orbit——

Mr. FUQUA. For the first stage.

Dr. MARK. No, sir. You take three solid boosters, strap them together, build a frame that allows you to launch them from the same pads that we have for the shuttle. There is no investment in launch facilities. There is a small investment you have to make in a few modifications, but you don't have to build anything brand new.

These things, of course, as Mr. Beggs said, if we did that, we would be able to use the same production base that we have for the shuttle. If you use shuttle main engines, then you really have something, because you can conceive and build vehicles of the order of a half a million pounds in lower Earth orbit in one flight. Some believe that the right way to retire the old engines after we get through using them on the shuttle is to fly them on one of these expendables and leave them up there.

I think there is a whole new world here of launch vehicles that we really have to look at very carefully in this whole decision of what kind of unmanned launch capability we want to have.

Mr. FUQUA. That is a very interesting phenomenon, and I think it is one that we should pursue. I am still concerned, though, in Mr. Beggs' response that if we are talking about making a decision on a fifth orbiter in 2 to 3 years that then we impact the maximum budget peak of the space station whenever that is decided. That concerns me because of what it does to the rest of NASA's budget. That is a real concern based on that assumption.

There is another statement, Mr. Beggs, on page 7 of your statement relating to the ACTS program. You indicated that recently private companies had made a proposal to build satellites with their own money and do some of the things that we had planned to do with the ACTS satellite. How many private companies have made that indication?

Mr. BEGGS. Well, we have one that has made a filing with the FCC for a license in that frequency.

Mr. FUQUA. Your statement indicates plural.

Mr. BEGGS. We have seen some other interest, but no other filings as yet. There is one that has filed for a license to launch in that part of the spectrum, 30/20. Our feeling was, and they did this late last year, our feeling was when they came in and told us that they were going to do that that if we have a commercial entity that feels the technology is at the stage where they can go commercial with it and compete at that level, then we certainly ought to, ourselves, retire back to the drawing board, back to our laboratory and decide what the next step is rather than fly what we have got now. We have done that. That is our recommendation.

Mr. FUQUA. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you. I now recognize the gentleman from New Mexico, Mr. Lujan.

Mr. LUJAN. Thank you, Mr. Chairman.

One of the things that I have been concerned about is this whole questions of industrialization of space. We talk about it quite a little bit, and I know that we are moving into that with the ELV's and those sorts of things. I would like to focus on the space station.

When we say that we want the involvement of the private sector, are we talking about their contributing to the base program, paying some of the base space station expenditures, giving them the opportunity to build their own little cubicle attached to the station or are we talking of being a landlord where they pay rent? What kind of things are we talking about when we are talking about the industrial, private sector being involved?

Mr. BEGGS. Really, all of the above. We have heard from business concerns who are interested in investing in the capability with an eye to getting a claim on some of the services and some of the facility. We have talked with some who have indicated they would like to rent or lease space up there when we get it operational. We have talked to others who have said they want to put their equipment on a platform which we would tend for them and replace consumables when it was necessary, take off finished products, and bring it back to Earth. We have talked to some who want to add a module.

Now, obviously, as you work your way up that scale, you are talking about increasing sums of money, and the latter is a several hundred million dollar investment. Whether there is that much venture capital out there that is willing to bet on the come, we will have to see when they come with money. However, they have been in, and some of them quite insistent that they can raise large sums of money.

You might be interested that just in the past year, in the venture capital market—and the Congress provided the mechanism which this market works, these limited partnerships for R&D that were set up under the tax act the last time, there has been raised something in the order of $100 million of venture capital to invest in space-related R&D kinds of activities which will lead to products which they can sell. So, the money is there. It is a question of whether they can put together a commercial proposition which will attract that money.

Mr. LUJAN. What are we going to use the $150 million for, this first $150 million? What sorts of things will happen in the next year?

Mr. BEGGS. A whole host of different things. We are going to spend it for studying the mission requirements further. We have done a little bit of study on that previously, but we are going to study mission requirements, the way in which we are going to accommodate the various customers we expect—by customers I am talking about not only commercial but science and the various and sundry individuals who might want to join us in some mission objective using the station.

We are going to do a good deal of looking at what the architecture ought to be, what that really should be. What I have sitting over there is a conceptual model—what the architecture of that should be, what the system and subsystem requirements are for that in the various utility areas, power, consumables such as water, fuel, and all the other things that we will need to operate effectively up there, the technology requirements in life support, technology

requirements in telecommunications, technology requirements in computational capability, the understanding of the various and sundry facilities. We will have to provide test beds in using the station effectively, work on robotics and automation. We are talking about a station of six to eight people, perhaps eight, and in order to make them very productive and you are going to want them to be very productive, we are going to have to enhance their ability to operate with robotics and automation.

John Hodge and Phil Culbertson, when they get before the committee, have a very detailed list of how they are going to spend the money beyond that, and I am sure they would be very pleased to discuss that in detail.

Mr. LUJAN. How are we doing on the space telescope?

Mr. BEGGS. We are doing reasonably well. We are holding schedule, that is, the new schedule that we told you about last year. We are holding schedule and we are still holding to the cost that we submitted to you last year. It is not without some continuing problems. There are some, I should say, new problems, but we have worked our way through them. We are working toward a date of late this year, the third quarter of this year, maybe early in the fourth for the shipment of the OTA, the optical telescope assembly out to Lockheed where they will start assemblying it into the complete assembly. We are on schedule to do that.

The one problem that was concerning everyone last year on the telescope was the fine guidance system, and there were some who were worried at that point that the approach we were taking on the fine guidance system would not work, that it was technically unfeasible. I am very happy to report that we have the fine guidance system and it does work. It works to meet the specification and it appears that it will allow us to use guide stars of even fainter magnitude than that which we specified.

Do you want to add anything to that, Dr. Mark?

Dr. MARK. No, I think that covers it.

Mr. BEGGS. At any rate, we are satisfied with the progress for the moment, Mr. Lujan, but we are still watching it very carefully, I can assure you.

Mr. LUJAN. Finally, because I know my time is running out, TDRS related—you said we still don't have it fully operational. Could you tell me what some of the problems are and leading towards the second TDRS?

Mr. BEGGS. There are a few minor problems on the subsequent satellites, themselves, which we are working on. We had a little bit of a problem on a traveling wave tube amplifiers in the higher frequency band on the first one. However, those I would characterize as minor development problems and we will fix those without question before the second one is launched.

The major problem we have is in getting a fix on the IUS that both we and the Air Force fully believe in in terms of the reliability of that stage. We have run a couple of tests, and they have been inconclusive. That is my term for saying we probably did not succeed in those tests in correcting our problem. We will run further tests late in February which I hope will give us some insight as to what we have to do to make it work completely satisfactorily.

I might say that the DOD probably has as much of a stake if not a greater stake in this than we because they have payloads of their own that need the IUS to fly. So, they are working very hard and we are working with them. We have a joint program and a joint team working with the contractors in trying to find the source of the problem and correct it and, obviously, correct it as quickly as possible, because it is February and we are still hopeful of getting our second bird off before the end of the year. So, time is of the essence.

Mr. LUJAN. Thank you.

Mr. VOLKMER. In that regard, I would like to continue on with that just a minute, and if you don't have the information, perhaps Mr. Newman can get it and submit it in writing. Because of the malfunctioning of the TDRS, and as I understand it, it is the up link that is not operating properly; the down link is, and also the fact that we don't have the second one up there, I would like to know the budgetary impact that that means as far as next year's budget. In fact, we have to get the ground stations operating and continue them, and I would like to have that as to how that is impacted.

Mr. BEGGS. We will give that to you in detail, but in rough magnitude, it is costing us about $5 million a month for the ground station, which we would have since been able to eliminate if we had had the system operational, the three of them.

[The information follows:]

The impact of the IUS Anomaly on the FY 1985 Office of Space Tracking and Data Systems [OSTDS] budget is estimated at $57 million. This estimate assumes the successful launch and checkout of TDRS-B and TDRS-C in November 1984 and February 1985, respectively. Of the estimated $57 million, approximately $33 million is associated with the TDRSS Project and the balance of $24 million is for operating the stations including the communications through March 1985.

No provision was made in the OSTDS FY 1985 budget request for the TDRS K-Band problems since they were not known at the time the budget was being developed. The matter is still under investigation and the impact of the K-Band failures cannot be assessed at this time.

Mr. VOLKMER. The Chair will now recognize the gentleman from Virginia, Mr. Bateman.

Mr. BATEMAN. Thank you, Mr. Chairman.

Mr. Beggs, it is very nice to have you back before the committee again and to get this overview of the program for NASA that is proposed for the coming fiscal year, and certainly we recognize that that program functions only so well as it is budgeted and appropriated.

In an area of particular concern to all of us on the space station, to the extent there is presently a design concept and as far as that concept has been taken, where is that responsibility within NASA being carried out?

Mr. BEGGS. We still have operational, Mr. Bateman, the task force we created a couple of years ago to study that, and we have drawn on each of our centers.

If I may, I would like to comment on that. This project is unique in that respect, in that the various techniques and systems and technologies that will go into the station are everywhere in the NASA system, so all eight of our centers will have a major role in this program.

We will, without doubt, set up a management office in NASA, probably headed by an associate administrator, within the next 6 months to be the management authority for the program. In addition to that, as our studies progress to the point where we feel we are confident of the way we intend to manage this, we will then establish a lead center, perhaps within the next few months. That will undoubtedly be Johnson.

Mr. BATEMAN. Let me, if I may, turn to a very general area of concern. You have indicated that the space station initiative which certainly I applaud—I hope all of us do—is not something that is being done at the expense or jeopardy of other scientific programs at NASA. When you get to the presentation of your budget for the aeronautics aspect of NASA, I assume we will not be finding any diminution of funding for any existing aeronautics research programs?

Mr. BEGGS. I am going to ask Dr. Mark to respond to that if I may, Mr. Bateman.

Dr. MARK. As you know, sir, the NASA budget is built from the ground up; that is, we are not given a total figure and then trade off things within that figure. I think the aeronautics program, especially, as you know, is something that is close to my own interests. We have proposed a substantial increase this year in our aeronautics programs, particularly with respect to some of the things that Mr. Glickman's subcommittee was concerned about, namely the creation of new experimental aircraft. One of the large increases this year is the X-wing experimental vehicle that we will working together with the Army on. So there really is, in first order, no impact at all on the aeronautics program.

Mr. BATEMAN. So I take it you don't anticipate the termination of any present aeronautics research programs that are in progress before completion of the programs?

Dr. MARK. Well, if we do phase down programs, they will be phased down for internal reasons within that program and not because we are doing something else. In other words, they will be phased down because something is finished or because we cannot see the requirements for them, but not because we are going to go off and do a space station.

Mr. BEGGS. If I may add just this short comment, overall, the aeronautics budget in 1985 is up over 13 percent from 1984, so that it is a healthy increase.

Mr. BATEMAN. I notice the gross figure, and certainly, Mr. Chairman, if I have a moment more, I would applaud the fact that we are concluding—hopefully, successfully—some of our aeronautical research programs. I would be a little less nervous if I had heard that we were not closing down any which are in process and which show promise, but we will pursue that at another committee.

Mr. VOLKMER. The Chair now recognizes the gentleman from Pennsylvania, Mr. Walker.

Mr. WALKER. Thank you, Mr. Chairman.

I am going to ask a couple of questions about the space station, too, if I could.

To what extent is the station that you are contemplating as far as design going to be an expandable kind of unit? Are we talking here about designing a station which is an 8- to 9-person station

that is expandable to 100 people at some point in the future, or are we talking simply about building a station that is 8 to 9 people?

Mr. BEGGS. No, we are talking about a station that is expandable or can grow. Whether it can grow as much as you just suggested, I would not hazard a guess, but certainly it can grow to much larger size than the current eight or so that we are contemplating.

Mr. WALKER. I don't hesitate to overstate the case at times, but I would like you to think in those terms.

Dr. MARK. Just a point: Eventually, you run into technical problems; that is, you run into problems having to do with ability to control very large structures, so we have to learn some of these things.

Mr. BEGGS. But once you have developed the first capability, it is relatively inexpensive to replicate that with another one which can fly.

Mr. WALKER. Insofar as you could utilize the concepts that Dr. Mark talked about before of using the shuttle boosters as a flight vehicle in themselves and lifting much heavier loads, can we talk about modular concepts for the space station that would be far larger than what we can carry aboard the shuttle, and is that one of the things that is being contemplated in terms of assembling the station?

Mr. BEGGS. Well, we are talking about assembling this station on orbit, and so we are talking about components that will be larger than a single load on the shuttle. But long term—that is, as we get the station operational—we are contemplating developing techniques for constructing the very large structures that we have been dreaming about for the last 20 years, because those large structures enable you to do tasks that you cannot do now. Such things as very high capacity telecommunications, for example, require a large antenna, a directional antenna, and the generation of large amounts of power in space.

I am not referring here now to the idea of generating power and transmitting it back to earth yet, but generating very large amounts of power in space, which enables you to do things in space that you would like to do, which have been inhibited by the lack of ample power.

This concept we are looking at over here, which uses the large solar arrays, is about 75 kilowatts in electrical power. To give you an idea of why it has been limited, 2.5 kilowatts is about, well, it is less power than the average home is consuming, for example, a home like mine whose wife likes electrical gadgets; it uses a lot of power. If I can add this comment, that is more power than we have put up on all of the solar-powered systems in the last 25 years, in the aggregate.

Mr. WALKER. And, of course, that has some bearing—as a matter of fact, it has a very direct bearing—on the expandability of your station, too. For that reason, are you doing any investigating of the possibility of flying nuclear powerplants for the station?

Mr. BEGGS. We joined together about a year ago in a study effort with the DOE and the DOD in the study of large nuclear power sources. By large, I am talking about up to maybe 500 kilowatts or even up to 1 megawatt of power, starting at several hundred kilo-

watts. We are still engaged in that with the DOE and expect to continue it.

There are a lot of reasons why, for the future, you would like to have a very power-rich environment. If the commercial era arrives in space, the one thing you are sure to need is a lot of power. And so, yes, this 75-kilowatt solar array is about the largest that you can contemplate using current technology. If you want to go beyond that into the couple hundred kilowatt range, you have got to think about nuclear power.

Mr. WALKER. It is my understanding that DOD has not been completely supportive of that program on nuclear power in space. Is that the case or not the case?

Dr. MARK. No, sir. There is a tri-party memorandum of understanding between the Energy Department, the Defense Advanced Research Projects Agency, and ourselves to develop this thing, so there is no problem there at all. As a matter of fact, I was in a meeting in Albuquerque 2 weeks ago on space nuclear power, and several representatives were there from the Department of Defense, so there really is no problem.

Mr. WALKER. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you.

The Chair now recognizes the gentleman from California, Mr. Mineta.

Mr. MINETA. Thank you very much, Mr. Chairman.

I would like to, as a new member of this committee, welcome Mr. Beggs and Dr. Mark and Mr. Newman.

I would like to ask, just in terms of the way, I guess, decisions get made, within the administration, you have what is called the senior interagency group, and this plays a major policy role in setting national space policy.

I think this is of concern to the Congress, since the formulation of policy and accountability for policy recommendations become somewhat obscure and obfuscated. So I am wondering, what role does NASA play in the Senior Interagency Group on Space?

Mr. BEGGS. Well, I am a full member of that interagency group, Mr. Mineta. I attend every meeting and participate in all of the various discussions that go on in that, and I think we have a good strong voice in that group.

Mr. MINETA. Now, are there any policy areas that NASA reserves for itself?

Mr. BEGGS. Well, there are no policy areas that we reserve for ourselves, but we certainly take the lead in those areas and discussions which relate to the civil side of space, and in any area that reflects itself on the future R&D effort in space, because the technology development we look on as being a very special piece and part of what we are supposed to lead. In fact, that is sort of one of the things that the statute gives to us as being a prime responsibility. We do take that seriously.

Mr. MINETA. As you may be aware, I also wear another hat in serving on the Intelligence Committee, and I am just wondering, in your view, why DOD is now moving to reverse its earlier decision regarding the availability and use of ELV's.

Mr. BEGGS. I knew this was leading somewhere in that direction. They are studying that, and they have been studying it very active-

ly, I guess, for a year, and this is not something new; they have reviewed that question over and over, over the past several years, when the shuttle was under development. As a matter of fact, I understand, while I wasn't around this town, I understand that at the time that the shuttle slipped its schedule, they looked very hard at going back to establish a strong capability in ELV's.

There are several ways one could do that, and in doing it in any one of those several ways, it would have a more or less effect on the shuttle system itself. Dr. Mark spoke earlier about the potential of a shuttle-derived ELV. If there is a need for a backup—and that is one area that I am not competent to judge for them, as to whether they absolutely have to have a backup. I have my opinion on it, but I can't judge it. If they say they do, they do. If they need a backup, then I would urge that the backup be a shuttle-derived expendable, and for any of several very good reasons.

First and foremost from the Nation's point of view is that such a vehicle would have very large growth potential. I think if you are going to go and keep an expendable around, if you are going to pay for having an expendable in your inventory, you ought to have one that will grow as new requirements come into being. So from a national point of view, the best one you can get is something based on the best technology of the moment, and we believe that is the solid rocket boosters that have been designed for the shuttle. They are the latest we have, and you can develop and produce a very effective ELV which has good growth potential to do that.

Second, if you do it that way, the overall program will contribute to the shuttle program instead of taking away from the shuttle program, in that, to the extent that you buy those vehicles, you will cover the overhead of the manufacturer who is producing at the same time hardware for the shuttle, and to the extent you buy them, you will be lengthening the production line, and you will get the advantage of a learning curve as you produce more. In addition to that, you can use the same launch facilities that are in being for the shuttle. Or if, conversely, you feel you need more launch facilities, more launch pads, those launch pads cannot only accommodate the new expendable launch vehicle, but they can accommodate the shuttle. It gives you greater versatility for both systems.

Last but certainly not least, your manpower, which is always with you, the manpower needed to launch this equipment or this new launch vehicle can be interchangeable, so you can share not only the common facilities but you can use the same cadre of trained manpower to do the job.

I think those arguments are significant. We are urging that the DOD, in their studies of the future, give consideration to that approach. The only problem that could be raised with that approach would be one of schedule. We think we can demonstrate that we could have such a new expendable available in the time period that DOD needs it. The cost trades have yet to be done. They are setting out to do them. But as far as I can see—and we have looked at the cost of the SRB's and the ELV-derived vehicles—and it would appear to us from those preliminary looks that it would be competitive in cost. But those cost trades need to be done, and they will be done, I am sure.

Do you want to add anything?

Dr. MARK. I think, just to add one point, Mr. Mineta, as you well know, I was sitting over in the Defense Department when the decision was made——

Mr. MINETA. I remember having conversations with you when I was sitting as a member of the other committee.

Dr. MARK. I think that the question of a backup capability was always with us, and as you know, I argued at the time to maintain backup, and your committee in fact helped us to maintain the backup capability.

We are really getting into a new era now. The vehicles that Mr. Aldrich is talking about are really no longer backups; they are now vehicles that are complementary to the shuttle, because if you read his proposal, you will find that he is talking about vehicles that don't exist today; that is, they are vehicles that have the same capability as the shuttle, whereas the backups we were talking about before were less capable than the shuttle. They were the old Titan vehicles.

Now, I think that in terms of the requirements for such a complementary vehicle, we are not in a position to comment. There are reasons that you can propound that would say yes, you might want to have such a capability. I think on the technology that we employ to get that capability, we are very much in a position to comment, and there I would thoroughly endorse what Mr. Beggs has just said about using the shuttle technology, the advanced propulsion technology that we now have, to create this complementary generation of unmanned launch vehicles, rather than going and using 30- or 25-year-old technology on Titans and Atlases and straining to upgrade that.

Mr. MINETA. To that extent, is that complementary or is that competitive?

Mr. MARK. It is very highly complementary, as Mr. Beggs just said. You use the same production base. You use the same people to do the launches. You use the same vehicles, the same solid rocket boosters and the same engines, and most important of all, you have a set of building blocks here that allows you to build an enormous growth potential into this whole thing.

We have conceptual designs for launch vehicles built out of solid rocket boosters and shuttle main engines that can get up to half a million pounds into low-Earth orbit. That is compared to our current 60,000 pounds as the best capability.

If we go to the shuttle-derived launch vehicles as satisfying Mr. Aldrich's requirement for a complementary unmanned capability, we get all those advantages, and I would urge very, very strongly that the Congress consider that very carefully indeed.

Mr. MINETA. In the area of international cooperation on space projects, historically, NASA has found it necessary to begin negotiation with other countries prior to full program authorization and approval. Program deferrals or cancellations have often resulted in ill will. What mechanism can you envision which would allow such negotiations to take place in good faith without the prospect of such cancellation?

Mr. BEGGS. It is a difficult question. The Europeans, in particular, are very sensitive to this because of the ISPM cancellation here a few years back; that is, the American side of the ISPM can-

cellation a few years back. The one thing that we cannot get around, at least under the present system, is the fact that there is a yearly appropriations process here in the Congress, and it is conceivable that in one of those appropriations processes, either the OMB or the Congress will decide that one or another program is not worthy of continuation.

The European system, as you know, Mr. Mineta, is different. When the parliamentary systems authorize and appropriate for a new program, they generally appropriate or provide a kind of contract authority that lasts through the entire program, so they agree they are going to go forward, that they will sustain the program to completion, even though they do have mechanisms to cancel if the programs turn out to be not worthy of further funding. So, we have a problem with that in this case. They are going to ask us, how can we assure them that we are going to continue for several years, in light of the fact that we have had this bad experience.

My response to that has been, and I am sure will be, that we have initiated many programs with international cooperation in the past, and the vast majority of them—in fact the ISPM mission is perhaps the exception that proves the rule—the vast majority of them have been sustained through the program.

We have been working with ESA to try to draft some language which, if we can ever arrive at suitable language, we will, of course, submit it to the Congress, to try to work out some way that will at least make them feel a little better about this. But, I don't think that we are going to fully allay their fears unless there is a change in the way in which the executive and the legislative branches of this Government conduct their budgetary process for these long-duration programs.

Mr. MINETA. Is there any time line with ESA on coming to some conclusion?

Mr. BEGGS. Well, we have some prospective language which I think we completed discussions on with them last year, which appears to be reasonable, and I will be talking to them further on that, I expect, in March. They are going to be discussing with us cooperation on the space station, I believe, in March, and we will probably hear more about that then.

Mr. MINETA. One quickie, and that is, do I understand you are pretty much on schedule on what is happening out at Vandenberg in terms of construction?

Mr. BEGGS. We are on schedule, but——

Mr. MINETA. We had a slip on that before.

Mr. BEGGS. I would characterize the current schedule as being extremely tight, as I see it. That is my view, not the Air Force's view. We work very closely with the Air Force out there. We have people out there assisting them, and so I am privy to the schedules and to the progress on the job. My judgment would say that it is very tight and that there is some risk of some slip, although the slip, if any, will not be very long. We are talking about months, not years; that is, a few months rather than years. But they are still holding to the schedule that you have received in prior years. They have not changed their schedule from that. It is just that it is getting tighter and tighter as time goes on.

Mr. MINETA. Thank you very much, Mr. Beggs.

Thank you, Mr. Chairman.

Mr. VOLKMER. The Chair now recognizes the gentleman from California, Mr. Brown.

Mr. BROWN. Thank you, Mr. Chairman.

Mr. Beggs, my personal reaction to the presentation that you made and the budget figures is one of mild euphoria compared to what we have faced in the past. I like the idea that we have a 5-year plan that provides for some small but real growth in the program. Presumably, as the funding on the shuttle decreases somewhat, it will allow further opportunity in some of the other programs.

Are you reasonably well satisfied that this gives us a positive outlook for the future in the space program?

Mr. BEGGS. Yes, I am very euphoric about it, Mr. Brown. I think it is a good program.

The one thing that we all know that this program requires is steady levels of funding, because we don't start anything that doesn't require 7 to 10 years to accomplish, and so in order to lay our plans and to accommodate the many problems and issues we run into over time, you have got to be assured of steady funding. The thing that kills an R&D program of this type is an up-and-down kind of action in the budgetary process, because when you go down, you lose your people; you lose the continuity in the program, and when you restart, you don't get the same people back, and the chances are that you replan the program.

So that start-stop or up-and-down technique is really disastrous. But, if we can be assured of level funding for a significant period of time, I think we can accomplish an awful lot.

Mr. BROWN. I notice that you comment on the fact that this gives you the ability to acquire several hundred new scientific and technical people this year, next year, and that that will have a beneficial effect, and I concur with it.

We discussed this up-and-down funding with Dr. Keyworth this morning, and he expresses essentially the same views you have, and I think this may be one of the most constructive things that can be done, and that is to recognize the importance of providing this continuity.

Let me ask you about the space station, which we are all very much interested in. Are you sufficiently far along that you have a feel for what the orbital parameter is going to be? This will be launched from Kennedy and will follow an equatorial orbit, generally speaking?

Mr. BEGGS. Without doubt, we will launch into the 28½-degree inclination orbit that we have used so much out of Kennedy. That just happens to be a good orbit and one in which you can achieve the—and so it is very likely that will be the inclination. That is a good one to do most of the scientific. The only thing that that does not give you is complete coverage of the globe for Earth observations, but it looks like a good one for all the other science that you would like to do.

The altitude that we will be in is somewhere in the 150- to 250-nautical mile range. We have not really set on that, but that looks like a good altitude.

Mr. BROWN. You mentioned that the station will have the capability for both looking up and down, and we have, of course, seen some fascinating photographs from the shuttle taken by astronauts, I guess using fairly conventional cameras, but also some of the side-looking radar pictures which were extremely useful.

Mr. BEGGS. Yes.

Mr. BROWN. I missed most of your presentation, and I am interested in the international participation, and I don't want to belabor it, but I presume there is an element of inviting participation from other countries to join us in this.

Has that gone so far as to include the possibility of including the Soviets?

Mr. BEGGS. No, sir, not at this time. We are still doing a little work with the Soviets, and we, from time to time, have overtures on both sides to expand that, but right now there is nothing active in that interchange.

As you know, the Soviets have a space station program of their own which is very active. I don't know what their reaction would be, but we have not contemplated approaching them with this one at this time.

Mr. BROWN. Well, I think you can envision their reaction, and that is that this is another effort to disadvantage them in some way. Their posture with regard to the shuttle was that this was an antisatellite weapon, and they are likely to take similar views with regard to the space station, that we are going to mount lasers up there or something to destroy their installations of one sort.

I recognize all of this, and yet it seems that the President is inclined at this point to be somewhat more conciliatory toward the Soviets, and it is my personal view—and I don't suppose it is very widely shared in the Congress—that we could avoid a lot of problems, since this is not a classified project, if we took advantage of our mutual strengths and invited them to participate in a station of this sort.

It might be one of those confidence-building gestures that would achieve some of what the President is trying to achieve at the present time. Is there any possibility that that——

Mr. BEGGS. Well, I think, looking back into the early 1970's when we initiated the Apollo-Soyuz cooperation, that certainly seemed to have a beneficial effect at that time. The problem with a project such as this is that what we are talking about here is an 8- or 10-year effort, and getting a program initiated with the Soviets, let's say, in 1985, and expecting the relationship with the Soviets to remain stable through 8 years, is something that I guess I——

Mr. BROWN. You are not hinting that this might be just a 1-year effort that we are presently into?

Mr. BEGGS. No, no, I am not saying that at all. What I am saying is that on their side, and on our side, too, if you are going to continue the collaboration over a long period of years, one would hope that the relationship between the two countries would remain fairly stable from a foreign policy point of view, and I cannot think of any 8- or 10-year period where our relationship with the Soviets has remained stable. But be that as it may, I take your question very seriously, and we will continue to look at that and make proposals within the administration. But I don't know about long-term

collaboration with the Soviets. We have had some good collaboration in short periods of time, is what I am saying.

I did not explain fully that the Apollo-Soyuz was initiated in 1972, and we flew in 1974, so it was a very short-term joint mission, and it worked well. But what would happen if you initiated something over an 8- or 10-year period, I think we ought to think about before we do it. We have done a lot of other short-term work with them. We just flew with them, as a matter of fact, on a biotechnology satellite that they flew late last year. We can continue to exchange data with them from time to time, and we are cooperating with them whenever it appears that our mutual interests are served; for example, the SARSAT exchange where we are putting up a system of satellites to do search and rescue.

I am open to this. My mind is not closed to collaboration with the Soviets at all, and I wouldn't like to leave that impression with you. I am just saying there are problems in initiating a long-term relationship.

Mr. BROWN. I understand the problems, but the Apollo-Soyuz project was initiated by a very well known anti-Soviet president, and it seemed to be constructive at the time. As you say, we are still exchanging data with them. We are exchanging, I understand, data on the Halley's Comet mission as well as some other things.

It seems to me that the problems are mainly psychological. If we expect that we are not going to have good relations with them and therefore don't initiate things, that almost creates the reality of what we are expecting.

On the other hand, we have had some Members of Congress, including some very well respected—not in my class, but more respectable Congressmen—who have suggested joint confidence-building measures with the Soviets, including in the space area, joint communications, joint military observers, some other things of that sort.

The point is that if we really believe that our future lies in building better relations, not worse relations, we have to initiate some of these things, where they don't do us any harm and can only benefit us.

Mr. BEGGS. I agree. This is an arena which fits those various criteria that say this is one that we ought to be able to collaborate in. I will take your comment seriously.

Mr. BROWN. I appreciate that, Mr. Beggs.

Thank you very much.

Mr. VOLKMER. The Chair now recognizes the gentleman from Florida, Mr. MacKay.

Mr. MACKAY. Thank you, Mr. Chairman. I apologize for being late.

Mr. Beggs, we met with Dr. Keyworth this morning about R&D generally. I would like to ask you about the funding of the $9 million for transfer of technology from NASA research to industry. That is a level amount from last year. That was a subject of part of the conversation this morning. Do you feel that that is a sufficient level of funding to show priority for this area?

Mr. BEGGS. I think we can do an adequate job within that amount of money, Mr. MacKay. The more money you spend in this area, obviously, the wider you can disseminate your results.

There are in the business communications field, particularly, some important developments that have taken place in the last several years, and we are trying to take advantage of those. For example, there are now subscriber services available to business where they can, for the payment of a monthly fee, have access to an index of technology development. We are putting our data into those indices. We have hired the AIAA to assist us in that task. We continue our efforts to try to attract larger audiences to come to the various symposia and the quarterly meetings that we hold at one or the other of our centers for industrial participants both large and small, and I might add we are getting a lot of small ones, which encourages me, to come and get to know us and to understand what our research program involves and how they might take advantage of it, and we are getting more inquiries in that respect.

Obviously, if you spent more money in this area you could disseminate more, but I think it is an adequate sum of money.

Mr. MACKAY. You recently had a mission study, and it made recommendations that, in effect, you separate out shuttle operations and the rest of what you are doing, and then it also made observations, I believe, about coordination with the National Science Foundation. Are you now the lead agency for the exploration of space?

Mr. BEGGS. Yes, sir. I will be unequivocal. Yes, sir, we are the lead Agency.

Mr. MACKAY. Are you designated as the lead Agency?

Mr. BEGGS. Yes, sir, by law and by policy.

Mr. MACKAY. So if we want to ask what America's policy is toward space exploration, we can ask you?

Mr. BEGGS. Yes, sir, by law and by policy.

Mr. MACKAY. I see. All riqht. If I were to ask you at this point, what is it? Has that already been asked?

Mr. BEGGS. What is our policy? Our policy is to conduct the programs in science and technology both in the areas of technology improvement and in the areas of mission types, developments that enable us to maintain the preeminence of the United States in space, both science and exploration.

That was reaffirmed by the President's space policy published last July.

Mr. MACKAY. All right, thank you.

Thank you, Mr. Chairman.

Mr. VOLKMER. The Chair now recognizes the gentleman from Florida, Mr. Nelson.

Mr. NELSON. Thank you, Mr. Chairman.

I want to say congratulations to Mr. Beggs on conducting one of the most astute and adroit campaigns within diminished resources, to come out with a commitment that we have all needed, and to get that commitment from the President. I congratulate you with regard to the space station.

Basically, you are looking at a budget that has about $150 million increase for the space station, and the only other new thing in it is really, you are looking at about $150 million additional on the TDRS. So, other than that, you are pretty well status quo except mixing around some priorities. Is that about right?

Mr. BEGGS. Well, let me try to characterize that a little differently, Mr. Nelson.

First of all, I thank you for the compliment, but the President was very deeply committed to this program himself, and I think a lot of credit should go to him. He is very much behind this initiative. With respect to the budget, what we have is a budget which has relatively little growth in real terms. The OMB would argue it has some growth in real terms, since the inflation rate this past year was down to something over 3 percent and they expect a similar performance or maybe a tad better in 1985.

Mr. NELSON. Well, may I stop you right there? Let me question that. In the statement that you handed out in your press conference a couple of days ago, you said it is about a 4-percent increase.

Mr. BEGGS. Right.

Mr. NELSON. But the inflation figures, by the administration's assumptions, for fiscal year 1985 are 4.7 percent. So that is not a real growth of anything; that is a net decrease.

Mr. BEGGS. Yes; I am saying that the real performance of the economy in 1983 was something over 3 percent. If you make the assumption that it is going to grow higher than that in 1984 and 1985, then there is no real growth. I don't make that assumption, but anyway, what I was getting to was a different point, and the different point is that the difference between this budget submittal and last year's budget submittal is in the out years, in the next 5 years. We have a proposal to maintain the NASA budget at a constant level plus 1-percent growth. In previous years, it had always contemplated a downward trend in the budget as programs finished up. It was, if you will, not a realistic assumption that that would happen, and I think we have put realism in the budget this time and that the increases in the out years, as programs finish and new programs start, will allow new initiatives and new programs to start.

Getting back to your question, though, in the aggregate, if you add the two numbers that you described, that would take up most of the increase that is provided from 1984 to 1985, but the facts are that in the give-and-take of programs finishing and programs diminishing and programs increasing, we have moved priorities around.

The science budget for each of the last 3 years, including the 1985 budget, has increased on a percentage basis substantially. The aeronautics budget has increased on a percentage base substantially. The transportation budget has decreased substantially, and our reimbursables have increased substantially.

All that makes possible the initiation of the new programs that we have asked the Congress to approve, among which are, most importantly, the space station, but also very importantly, the upper atmosphere research satellite and the new Mars observer, or planetary observer as we like to call it, MGCO. We think that is significant, and we think it provides a very firm base for entering the next development period. In NASA, we seem to reach these points when things end and new things begin and 10 or 12 years ago or thereabouts, it was the end of the Apollo program. Now we are approaching the operational stage of the Shuttle program, and we are moving into a new era, if you will.

The budget we are presenting here, we think, sustains the new initiatives. Obviously, when one looks to the future, one can always worry about the potential for problems or the potential for additional requirements overloading what we have, but we think we can manage within that because, as I said in response to Mr. Brown's question, the major thing that this program needs is stability of funding, not large increases but a stability of funding. If you promise us a set amount of money giving us maybe a tad of real growth; but, if you let us plan on that for 10 years, we will amaze you in what we can do.

Mr. NELSON. Mr. Chairman, there are two lines of questioning that I want to get out, and let me, if I may, before you bang the gavel on me, see if I can get these two points across.

First of all, I don't have any disagreement with what you just said, and I understand that you have the assumption that you have about a 1 percent real growth over several years. You want that consistency, and I understand that, and as an administrator, if I were in your shoes, I would want that, because that is what you need for good planning. That is what the Defense Department needs. They need a consistency instead of up and down, up and down.

What I am afraid of is—and I have looked at the figures—that you don't have that consistency, and the assumptions and the commitments that have been made, it seems to me, are not here.

For example, you say there is a 4 percent increase. That is true, but by that very same document's own figures, they are saying there is a 4.7 percent inflation factor, either measured by the GNP deflator or the CPI. That means you are at a negative 0.7, seven-tenths of 1 percent. You are in a negative; you are not in a real growth of 1 percent, which is the pledge to you.

Now, if you go further beyond the administration's figures and you take substantial economic organizations, respected, such as Chase Econometrics or Wharton School, they say that inflation is going to be 6 percent in 1985, and if they are right, instead of the 4.7, you are at a minus 2 percent real growth.

So what I am saying is, in order for the White House to fulfill its commitment to you, we had better relook at these figures, shouldn't we?

Mr. BEGGS. I think those are the same people who gave you a 7 percent figure for 1983. [Laughter.]

Mr. NELSON. I am only looking at what the administration says it is going to be, 4.7.

Mr. BEGGS. Yes, sir. I acknowledge that. The program we put together fits within the budget we are recommending. I am sure the Congress, in its deliberations, will decide whether there is too much or too little money in any of those line items. But we feel that we fit an adequate program within that $7.5 billion. As I say, some programs are increasing, some are decreasing. Overall, we have, I think, an adequate program within that amount of money.

The agreement that we made, however, in conjunction with that budget and as a result of the initiative the President made for a space station says that we can count on 1 percent real growth in the out years, and that agreement says as well that if the projections for inflation differ in the out years, we will still get that 1

percent real growth. I feel confident that we can conduct the program that we are proposing to you in those out years.

Mr. NELSON. Do you have a commitment that the administration will come forth with a supplemental if in fact inflation is in fact this, so that you get your 1 percent real growth?

Mr. BEGGS. No, I have no agreement that I will get 1 percent real growth in 1985.

Mr. NELSON. I see.

Mr. BEGGS. I have one agreement that we will get 1 percent real growth through the next 5 years.

Mr. NELSON. I see, an average of 1 percent.

Mr. BEGGS. Right. The budget works up to slightly over $9 billion in fiscal year 1989.

Mr. NELSON. All right.

The other line of questioning, and it probably has been touched here, and I apologize for being late—it was unavoidable—is this. Do you have enough funny money in here on spare parts and so forth to keep alive the option on the fifth orbiter without the production line having to shut down?

Mr. BEGGS. Yes, we do, but I have got to qualify that by saying that it is going to require some real hard work by our contractors to do that; that is, they are going to have to work very hard to make sure that they maintain that warm production line capability within the money we are spending on spares. The amount of money we are spending on spares and other capability improvements—we are going to be doing some mods on the shuttles that have been delivered and other things like that, upgrades, and so forth—between those two things, I believe, and I believe this because I have gone through that myself; I have run plants and divisions holding together a warm production capability during some pretty lean times, and I know it can be done because I have done it; that if we work that problem together, and I am sure we will—we have got to work it together—we can maintain the option to get another orbiter for another 2 or 3 years. But it is going to take a lot of hard headscratching, and I hope you ask the same question to General Abrahamson when he is up here with respect to the spares, and I hope he might even agree with me.

Mr. NELSON. I will look forward to General Abrahamson coming up.

Let me ask you this. If you have that much money, can you assign a percentage, x number of dollars would allow you to keep the production line open 100 percent on the fifth orbiter, but you don't have x number of dollars; you have x minus some sum. So what percent of the production line is kept open on the fifth orbiter?

Mr. BEGGS. That is a very hard question to answer, Mr. Nelson. You would probably need another, let's say, $100 million. But, gee whiz, that is the hard way to do it. We are going to spend, to give you the numbers, we are going to be spending over half a billion dollars on spares, including the structural spares. Next year we are going to be spending over $600 million on spares including structural spares. That is a lot of money, and it keeps a lot of the people employed productively and keeps a reasonably adequate skills mix,

and it keeps a cadre of, I hope, the best of your supervisory personnel, the guys who really know how to get the work done.

So the question you pose is a difficult one for me to answer in a specific number. It would take somewhat more money if you really wanted to make sure you were moving forward toward the fifth orbiter.

Mr. NELSON. Not only are you a good administrator, Mr. Administrator, but you are a good magician, too, with the sleight of hand, and I appreciate the delicacy of the position that you have had to face for the last couple of years on this instant issue.

Mr. Chairman, you had something you wanted to follow up there?

Mr. VOLKMER. I was just wondering, when we were talking about the contractors' capability, we are also talking about subcontractors and materials processors, et cetera, back down the line. As I understand it, some of these are already down.

Mr. BEGGS. Some of them are already down, and some of them, when we go back to them on a reinitiation, will not be in a position to give us the same product that we bought before, and that represents a problem for the future. But again, referring to the experience that I have had personally, when that happens, what generally happens as well—and it certainly is true in this field—the technology is not stopping. The Air Force, the Navy and even some industrial folk are buying subsystems of the type we use.

For example, if we had to redo the computer system in this vehicle, and our contractor had decided he no longer wanted to produce that 10-year-old machine that he provided—well, older than that—the 12- or 13-year-old machine that he provided for the initial shuttle, we would put in an even better computer. That provides an increased capability. It also means that we have problems because we are probably going to have to go back and redo some software.

But I think you would be able to cover yourself for the subsystems from the new stuff that is coming along. As a matter of fact, we see a lot of the new proposals from people who would like to come in and replace what now is 10- or 15-year-old type equipment.

I believe—and I really do believe this—that we will continue to have the option to buy another orbiter, but we are going to have to work—the major problem will be to work very hard to insure that the production capability out in our prime contractor is maintained at an adequate level so that when he starts up, he will be efficient. You can always start up and buy your way through problems, but we want to keep him so that he is efficient and so when he starts up, we won't have to pay an excessive amount of money to buy the next vehicle, assuming we buy it.

Mr. VOLKMER. Along that line, I am reminded of something we talked about when we were out in California earlier in December. We were talking to Lockheed, and if I remember right, they plan—and it may not be exactly right—sometime around April 1 of this year to go back on the tiles and the insulating, to go back to just very few just for spares, et cetera, that they will have fulfilled all the contract.

Mr. BEGGS. We have bought in most of the spare tiles we need. We still have a little bit of a problem there with some of the tiles that we are going to have to work with. But there is a capability

that I think can be reinitiated relatively quickly if we need to rebuild.

Mr. VOLKMER. Before I go on with any other questions myself, I will recognize the gentleman from California, Mr. Lowery.

Mr. LOWERY. Mr. Beggs, one final area that I didn't get a chance to finish up on earlier. With regard to the advanced communication technology satellite, it seems that there may be a little redundancy between what NASA has in mind and what Hughes is doing. Could you comment on that? How will the NASA system differ from Hughes?

Mr. BEGGS. It would differ in a number of different areas. We would use a different approach to the design of the processor or the system. We would probably use a different approach with respect to the antenna on the system. We probably would use a little bit different approach with respect to the switching system.

Do you want to comment further, Hans?

Dr. MARK. Yes. Let me get a little bit technical. The essential difference is that the commercial system that has been proposed is one that has a set of simultaneous feeds that operate at different frequencies for that antenna, and therefore—this is called a frequency division multiple access—and, therefore, you send down different messages on different frequencies.

Ours would have what is called a time division multiple access where you would use the same frequency but you would have a fairly sophisticated computing system that would divide the various messages in time. Our system has the advantage, of course, that if your band were limited—that is, if you are limited in the number of frequencies that you can use—it is more efficient than the system that the contractor has proposed. That is the essential technical difference. Otherwise, we would use the same communication band, the same frequency band, the same——

Mr. LOWERY. So you are saying that there is not sufficient redundancy that justifies NASA continuing with the project?

Dr. MARK. Oh, no, I didn't say that at all. What we are saying is this, that the technology to do the time division multiple access—that is, the technology to work out the system that allows us to chop up messages so that we can send them down on the same frequency—will be continued in ground technology development programs that we are in fact proposing in this budget. There is a proposal for a ground system that we will do.

What has happened is that by proposing to field a flight program in that same frequency range to do some of the other things, the commercial proposal has made it, in our judgment, unnecessary for us to do a flight program. That is the essential point.

Mr. LOWERY. You have scaled back, then, the ACTS program?

Dr. MARK. Yes.

Mr. BEGGS. If I can add just a word on that, Mr. Lowery, the issue that we constantly try to work is how far we should carry our technology, and we have, over the years, felt that our technology should be carried to proof of concept. Proof-of-concept means many things to many different people, but we have felt, on the high technology end, things like aeronautics and in this particular area of space technology, that unless you fly it and demonstrate it, nobody will pick it up and go commercial. But in this case, a private con-

tractor has come in and said, We are waiting at the gate; we've got money; and we are going to go forward; and you don't need to demonstrate it to us; we believe what we've got is adequate to enter the commercial market.

When they do that, we have got to go back and say, OK, you've got a guy here who is ready to go; let him go. Let's go back to the laboratory and demonstrate what we consider the next level of advanced technology.

Mr. LOWERY. Your decision was a prudent one.

Thank you.

Mr. VOLKMER. I have a couple more questions.

First, in regard to the reimbursables during the fiscal year, I would appreciate it if you would furnish the committee a breakdown of those and how those will be used. In other words, those that you receive on shuttle operations, et cetera, for that, do those actually just go back into shuttle operations, basically?

Mr. BEGGS. Yes, sir.

Mr. VOLKMER. In other words, I would like to know where those are, because those don't actually appear, if I am correct, within this budget on the line items in total. Is that not correct?

Mr. NEWMAN. You are correct. They do not appear within the appropriation requests. They do appear in the budget as a total document.

Mr. VOLKMER. Right, but I would like to have a breakdown on them for my own information.

Mr. NEWMAN. Yes, sir.

[The information follows:]

TABLE A.—NASA REIMBURSABLE ACTIVITIES

[In millions of dollars]

	FY 1984		FY 1985
	January estimate	Current	
SFCDC:			
Shuttle production and operational capability	134	211	177
Space shuttle operations	264	264	675
Expendable launch vehicles	180	210	98
Tracking	21	30	30
Subtotal	599	715	980
Research and development:			
OSF (Upper stages, etc.)	77	150	230
Applications, DOD support, TU, other	129	263	262
Aero R&T	25	50	36
Energy and techology	98	131	111
Subtotal	329	594	639
R&PM Subtotal	50	50	40
CofF subtotal	7	12	10
Total NASA	985	1,371	1,669

Mr. VOLKMER. And then I guess, more for tomorrow, when we get to Mr. Culbertson on the space station, I would like to know approximately the period of time that we are looking at this space

station, whatever it is—that is one idea—but whatever it is, how long? Ten years, 15 years, 20 years? How long are we going to be able to utilize it, and that type of thing?

Mr. BEGGS. Yes, sir, we will be prepared to discuss that.

Mr. VOLKMER. All right. Then the other thing that I would like to discuss right now a little bit, unless you will have the opportunity later, is on the OMV, and I understand the OMV is not in the 1985 budget. Is that correct?

Mr. BEGGS. The orbital maneuvering system is not in the 1985 budget as a new program, sir, but it is in there as a continuing study effort. We will spend probably in the order of $4 million or $5 million to continue to bring that concept along, because we do believe that is an important piece of what we see as the total system in the out years.

Mr. VOLKMER. Yes; but as I envision it, we are going to need the OMV before we have this station actually up. Correct or incorrect?

Mr. BEGGS. No.

Mr. VOLKMER. What about the space telescope? Possible defects?

Mr. BEGGS. The telescope uses the shuttle, and if we need to reboost it, we have that capability; that is, if we need to kick it up in the orbit into a higher orbit, we have the ability without the OMV. The OMV really is something that we would like to bring on at the time we have a station in existence so that we can move satellites and equipment readily from the relative low-Earth orbit all the way up to geosynchronous orbit.

Mr. VOLKMER. You won't use it in between low-Earth orbit and midrange or anything?

Mr. BEGGS. Oh, yes. Yes, sir.

Mr. VOLKMER. But you do not see the need to have it in operation before the station?

Mr. BEGGS. Not for the telescope and not for anything we envision in between, I don't believe. Hans, do you know of anything?

Dr. MARK. No.

Mr. VOLKMER. How often do you envision that we will have to reboost the space telescope?

Dr. MARK. That is an open question because it depends quite sensitively on conditions like sunspots and solar activity and so on. If you are very pessimistic—you know, if you have high solar activity, then it kind of boils off the top of the atmosphere and you have more resistance, and so you come down sooner. The pessimists say, in such conditions, you might have to boost it every 3 years. Under normal conditions, it is like 7 to 10.

Mr. VOLKMER. What are you planning for right now in the plans on the telescope?

Mr. BEGGS. Three-year intervals.

Mr. VOLKMER. How often would you have to if we had the OMV in operation?

Mr. BEGGS. Probably 5 to 7. It would lengthen the time.

Dr. MARK. It depends on so many things. There is no simple answer to that question because it really depends on what period of the solar cycle you are talking about, and so all we can give you are rough averages.

Mr. BEGGS. There are not a whole lot of data available.

Mr. VOLKMER. Perhaps at some other time we can continue with this discussion. But some of us are concerned about it, and at least I want to continue on that.

The other thing is, in regard to the two new starts, to get back to those as far as the planetary exploration and the planetary observers which were recommended by the Solar System Exploration Committee, as far as using the pioneer type of spacecraft, that is on board and that is pretty fair or is it a firm commitment for that for the future on that class of vehicles? I mean pioneer class.

Mr. BEGGS. You used the right word, Mr. Chairman, a pioneer class, as we would like to refer to them, and yes, we think that idea has been firmly kicked off in this budget.

Mr. VOLKMER. All right. Now, along with that, then, when you get to the Mariner/Mark II, which is not in here as yet—correct?

Mr. BEGGS. That is correct. The idea of larger missions which will undoubtedly occur at some time is not envisioned under this concept.

Mr. VOLKMER. As of this time?

Mr. BEGGS. That is not to say that they wouldn't be considered on their merits as they arose. We think that the one thing again—I keep referring to this, but it is true—the planetary community has complained quite loudly over the past several years because of the large intervals that have been between the probes that we have launched, and they say that because of that, it is very hard to maintain continuity; things disappear and people disappear in between the times you are thinking about probes; and they have urged NASA to come up with a program that would enable us to launch probes in shorter intervals, and I think this does that. It satisfies that requirement.

Now, as we learn from this new series of probes, there will undoubtedly be a requirement at some time to go out and do a much larger mission in order to explore something that is of very pressing and high importance that we discover as a result of our probes, and they will be considered on their merits.

Mr. VOLKMER. I want to thank you very much, Mr. Beggs and Dr. Mark and Mr. Newman, for your time here today.

We will continue our hearings. Our next hearing will be at 9:30 tomorrow morning in room 2325 on the space station.

The committee will be adjourned.

[Whereupon, at 3:44 p.m., the subcommittee recessed, to reconvene the following day at 9:30 a.m.]

1985 NASA AUTHORIZATION

THURSDAY, FEBRUARY 2, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:40 a.m., in room 2335, Rayburn House Office Building. Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Present: Representatives Nelson, Lujan, Andrews, Bateman, MacKay, and Torricelli.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

Today, the subcommittee continues our examination of the NASA fiscal year 1985 budget request. Yesterday, we heard from the NASA Administrator on the overall budget request including the President's space station initiative.

Today we will examine in greater detail the budget request for the space station and the closely related space research and technology activity.

Our first witness today will be Mr. Tom Rogers, Project Director of the Office of Technology Assessment, Civilian Space Station Assessment. This assessment was requested by both the Senate Commerce, Science and Transportation Committee and the House Committee on Science and Technology. Mr. Rogers will discuss the status of the OTA assessment as well as the issues and questions Congress should address in considering the Space Station initiative.

Our second witness will be Mr. Philip Culbertson, NASA Associate Deputy Administrator, accompanied by Mr. John D. Hodge, Director of the Space Station Task Force.

Our final witness will be newly named Associate Administrator for Aeronautics and Space Technology, Dr. John J. Martin.

Mr. Rogers, I would appreciate it if you would come forward and proceed. He is accompanied by Dr. Philip P. Chandler, Deputy Director of the Assessment.

I would like to state also prior to our beginning that Congressman Lujan from New Mexico will be joining us in a little while and he will have a statement also that he will give when he arrives. I will have to leave in a little while and we will have the chair assumed by Mr. MacKay from Florida at that time.

We will proceed at this time, Mr. Rogers.

STATEMENT OF THOMAS F. ROGERS, PROJECT DIRECTOR, CIVILIAN SPACE STATIONS ASSESSMENT, OFFICE OF TECHNOLOGY ASSESSMENT, ACCOMPANIED BY DR. PHILIP CHANDLER, DEPUTY PROJECT DIRECTOR

Mr. ROGERS. Mr. Chairman, the Office of Technology Assessment is pleased to be offered the opportunity to testify before you today. Over the past year, discussion has quickened regarding the kind of civilian space station, if any, needed to support our national interests in space. In our assessment, we are studying the issues related to the United States obtaining any such space capability. Our assessment is fortunate in being advised by an unusually broad and experienced panel, some from, but most from without, the space area.

We have issued one document, the OTA Technical Memorandum, "Salut: Soviet Steps Towards Permanent Human Presence in Space." Our study will not be completed for several more months; so the views expressed here, although carefully considered, must be taken with some reservation. However, inasmuch as it has been underway from some 16 months, we now judge that we are knowledgeable about the important circumstances in this area.

Let me underscore at the outset, that OTA does not take a position on the desireability of any space station. We do observe, however, that Americans will continue to go into space on the shuttle, and that the number of elements of space infrastructure will increase. The primary focus of our assessment, therefore, is not whether a space station should be built, but what are the issues and the options regarding the acquisition of space infrastructure elements.

A wide range of tangible and intangible reasons for obtaining a space station and various approaches to its design, procurement, and use have been advanced. The reasons encompass important intangibles prompted by considerations of exploration and adventure, energizing of innovation, and the national pride that captures our imagination and that of others. They encompass as well more tangible reasons, such as the conduct of experimental studies in scientific areas not presently available to us; the initial testing, servicing, and repair of equipment and free flyers; and the improvement of overall surface space transportation efficiency, and so on.

During the past few years, NASA began to focus on defining and obtaining the elements of a space station. At present, NASA favors a large and sophisticated ensemble of elements employing a great deal of new technology capable of supporting a human work crew, and apparently favors procuring it in what I would call the classical NASA fashion.

They now estimate that its initial cost to the Federal Government could approach $10 billion with the total cost approaching $20 billion. In the nature of large, high technology programs, it should not be surprising if the cost for all the infrastructure currently envisioned approached $20 to $30 billion by the end of this century.

As Congress addresses this matter, it is fundamental to their consideration of the issues that they appreciate that there is now no single thing that can be called the space station. There is, rather, a

large number of potential space stations that could be made up of various combinations of such inobit characteristics as onobit lifetime, volume, power, communications, local transportation, and so on.

Each characteristic chosen would have a particular value taken from a wide range of options. Given the space technology now available and that which has received extensive study, the number of personnel that could be accommodated range from, say, none to a dozen or more. The pressurized volume, again, from nothing to 10,000 cubic feet, a power available to users up to 200 kilowatts. Accordingly, the cost could be as low as $5 million for the smallest platform, to as high as hundreds of millions of dollars for a shuttle orbiter modified to allow an extended lifetime in orbit, or even tens of billions of dollars for sophisticated, essentially permanent elements that could support a large human crew engaged in many kinds of activities.

We have prepared a listing of some combinations of infrastructure elements that have received considerable study, their fundamental characteristics, their suggested needs which their capabilities could meet, their capital cost, and the time that it should take to obtain them. This listing accompanies our written testimony. From our study, we can identify, for instance, a set of infrastructure elements that would allow essentially all life science, material science, and plasma physics experiments to be conducted that have been identified by the scientific community as important.

It is our judgment that, by making good use of already developed technology, keeping required modifications thereto to a reasonable minimum, employing modern, cost-conscious, commercial-like acquisition practices, and cost sharing with other countries, the operational capabilities to meet these scientific requirements and to allow, as well, low-Earth orbit satellite servicing could be obtained for a total cost to the United States of some $2 billion. These capabilities, including four to six crew members, 10 to 15 kilowatts of power, and a space-based orbital maneuvering vehicle would be substantially greater than those provided by the Soviet Union's present space infrastructure.

To date, no major space-related objectives have been called for that would need publicly funded space infrastructure capabilities beyond those required for meeting these scientific ends. Furthermore, these capabilities could be augmented by the shuttle orbiter, the orbiter/spacelab combination, and free-flying platforms that could be available from our private sector and perhaps abroad by the end of a 5-year period. Therefore, requests for public funding of space infrastructure elements in excess of some $2 billion should receive particularly careful scrutiny.

It is important to note, Mr. Chairman, the specific words used by the President last week when he directed NASA to develop a space station and requested the Congress to authorize and appropriate funds to begin. He did not say "the" space station. He said, "a" space station. He allowed a decade for its development. He invited the participation of other countries, and he saw an enormous potential for space commercialization in relationship to it.

These criteria allow adequate time and sufficient flexibility for careful study of the most important uses to which any space infra-

structure would be put: the kind and amount needed, by when, how it should be procured, who should pay for it, and who should operate and use it. Most importantly, they allow time for a national debate and the setting of broad, agreed upon goals and objectives for space, for, Mr. Chairman, it is important to appreicate the space infrastructure is simply that: infrastructure. Its availability would allow certain space-related goals to be addressed and objectives to be accomplished, but it would only be a stepping stone to the achievement of objective ends.

The President stressed this point by saying, "But most importantly, a space station will not be an end in itself." That is a direct quotation, "But most importantiy, a space station will not be an end in itself." He stated that the country should reach for exciting goals in space.

The civilian space-related goals and objectives of the United States should be such as to command widespread attention, have great inherent humanitarian and scientific interest, foster the development of new technology, have relevance to global issues, prompt international cooperation, and involve major participation of our private sector. However, over the past decade, the Government has not studied and articulated such a national agenda of goals and objectives. In their absence, OTA concludes that it is simply not yet possible to judge objectively whether or not NASA's presently suggested infrastructure elements are truly appropriate and worth their substantial cost.

Parenthetically, and OTA has been making this point for over a year, we know of no broad and continuing professional study effort which could be used by our national leaders to see that the American public has the opportunity to consider and help initiate space-related activities that address important cultural, economic, social, and political ends.

The President has now taken a major step which raises the level of debate. His request for approval of another large and costly public space program should now prompt, indeed it now requires, a national debate about the United States interests and purposes in the civilian space area. Our great investment in space has now positioned the United States to do almost anything it seriously wishes to do in and with respect to space, and there are many promising opportunities to do so. What is now needed, to use NASA's own expression, is "the revitalization of the Nation's space program" and the reaching of an understanding that the Nation's civilian space interests are now broader than our Government's civilian space program.

Such a debate is prompted not only by NASA's presently expressed aspirations but by military, other-country, and private-sector developments and considerations. All of these sectors of our society, our universities, and particularly interested sectors of the general public now should move to participate in this debate.

Whatever the judgment of the Congress is regarding the administration's request for studies of space infrastructure over the next year or two, this time certainly should be used by both branches to see that the United States now decides upon and articulates again, in contemporary terms, its civilian space goals and objective. And, as we now approach the considered development of space, we

should be careful, above all else, that we not get caught up in either fascination with or the details of exotic space technology. What these times call for is not so much technical expertise—we have that in abundance but rather, vision, wisdom, judgment and leadership. We should all now focus on sensible methods whereby we can indeed develop America's next frontier.

To recapitulate briefly, Mr. Chairman, the energetic study, growing public discussion, and, now, Presidential support of a civilian space station is serving a most useful purpose that transcends consideration of any station itself. It is forcing us to reexamine our civilian space experience, our institutions and physical assets, our manner of acquiring, paying for, and using these assets to provide large-scale useful goods and services, and the influence of the space interests of other countries and of our own private and military sectors upon our publicly funded civilian space activities.

Today we have far too narrow and fuzzy a vision of our prospects in the space area. Without a clearer, more thoughtful vision, how can we expect consensus on our objectives? And without consensus, how can we rationally make long-term public commitments? Arriving at such a consensus should be our first order of business.

Mr. Chairman, thank you for inviting us here today. I trust that the completed OTA assessment, which will speak directly to all of the matters I have mentioned here today, will be useful to the committee when it is available a few months ahead.

[The prepared statement of Mr. Rogers follows:]

STATEMENT OF T.F. ROGERS, PROJECT DIRECTOR
ACCOMPANIED BY DR. PHILIP P. CHANDLER, DEPUTY DIRECTOR
CIVILIAN SPACE STATIONS ASSESSMENT
SCIENCE, TECHNOLOGY, AND INNOVATION PROGRAM
OFFICE OF TECHNOLOGY ASSESSMENT

Mr. Chairman, The Office of Technology Assessment is pleased to be offered the opportunity to testify before you today.

I am T.F. Rogers, Director of the OTA space stations assessment. I have a background in science, engineering, public administration and private investing, have been professionally active in the space area for 26 years and am a member of the National Acadamies' Space Applications Board.

I am accompanied by Dr. Philip Chandler, the Deputy Director of the OTA project. Dr. Chandler has participated in earlier OTA space assessments. He is particularly knowledgeable about those activities of the U.S.S.R. that involve its people in space.

* * * * *

Over the past year, discussion has quickened regarding the kind of "civilian space station", if any, needed to support our national interests in space. In our assessment, we are studying the issues related to the United States obtaining any such space capability. Our assessment is fortunate in being advised by an unusually broad and experienced Panel, some from, but most from without, the space area. We have issued one document, OTA Technical Memorandum "Salyut -- Soviet Steps Toward Permanent Human Presence in Space."

Our study will not be completed for several more months, so the views expressed here, although carefully considered, must be taken with some reservation. However, inasmuch as it has been underway for some 16 months, we now judge that we are knowledgeable about the important circumstances in this area, the issues, and the options available to the Congress in addressing them.

Let us underscore at the outset that OTA does not take a position on the desirability of any proposed "space station." We do observe, however, that Americans will continue to go into space on the Shuttle and that the number of elements of space infrastructure will increase. The primary focus of our assessment, therefore, is not whether people or machines are the more suited for working in space, or whether a "space station" should be built, but what are the options re future space infrastructure elements that the Congress may wish to consider.

* * * * *

A wide range of tangible and intangible reasons for obtaining a "space station", and various approaches to its design, procurement and use, have been advanced.

The reasons encompass important intangibles prompted by considerations of exploration and adventure, energizing of innovation, and the national pride that captured our imagination, and that of others, in the first two decades of the space age -- such intangibles as:

- o exhibiting continued space leadership,
- o exhibiting high technology prowess,
- o encouraging international cooperation,
- o maintaining a vigorous government in-house space engineering capability,
- o extending human presence in space,
- o promoting commercialization of space, and
- o enhancing national security.

They encompass, as well, more tangible reasons such as:

- o the conduct of experimental studies in scientific areas not presently available to us,
- o the assembly and checkout of large and sophisticated space structures,
- o the initial testing, servicing, and repair of equipment and freeflyers,
- o the provision of new commercial-industrial services,
- o the staging of long-distance, long-duration space flights,
- o the improvement of overall surface-space transportation efficiency,
- o the provision of a depot for human resources, fuel, and equipment,
- o the reduction of the cost of space activities, and
- o the initiation of personal travel into space.

Given these reasons, and anticipating the completion of the Shuttle development program, during the past few years NASA began to focus on defining and obtaining the elements of a "space station" -- in what is described by some as the next major "logical step in space." At present, NASA favors a large and sophisticated ensemble of elements employing a great deal of new technology capable of supporting a human work crew, and apparently favors procuring it in the "classical" NASA fashion. The total cost to the Federal Government of obtaining and operating such a "space station" would almost certainly be $20 billion, and, in the nature of large high-technology programs, the cost for all the infrastructure currently envisioned could approach $25- $30 billion (1984) by the end of this century.

* * * * *

As Congress addresses this matter, it is fundamental to their consideration of the issues that they appreciate that there is now no single thing that can be called "The" space station. There is, rather, a large number of potential "space stations" that could be made up of various combinations of such in-orbit characteristics as:

- Orbit,
- On-orbit lifetime,
- Volume,
- Stability,
- Thermal control,
- Safety,
- Power,
- Communications,
- Local transportation,
- Storage capacity, and
- Human accommodations: safe and sanitary living and working conditions for any men and women in orbit on an intermittent or full-time basis.

Each characteristic chosen would have a particular value taken from a fairly wide range of options. Given the space technology now available, and that which has received extensive study, the number of personnel that could be accommodated range from, say, none to a dozen or more; the pressurized volume, from 0-10,000 cubic feet; the power available to users, up to 200 kilowatts; etc. Accordingly, the cost could be as low as $5 million for the smallest

unmanned platform, or as high as hundreds of millions of dollars for a Shuttle Orbiter modified to allow a extended lifetime in orbit, or even tens of billions of dollars for sophisticated, essentially permanent, elements that could support a large human crew engaged in many kinds of activities and act as a staging base for distant space travel. We have prepared a preliminary listing of some combinations of infrastructure elements that have received considerable study, their fundamental characteristics, the suggested needs which their capabilities could meet, their capital cost, and the time that it should take to obtain them. This listing accompanies our written testimony today; we have already provided copies of it to your staff.

In our study, we have paid careful attention to the problem of finding a set of infrastructure elements that would allow essentially all life science, materials science, and plasma physics experiments to be conducted that have been identified by the scientific community as important. Although OTA has not performed a detailed engineering study, it is our view that by making good use of already developed technology, keeping required modifications thereto to a reasonable minimum, employing modern, cost-conscious, commercial-like acquisition practices, and cost-sharing with other countries, the operational capabilities to meet scientific requirements and to allow low-Earth-orbit satellite-servicing could be obtained for a total cost of some $2 billion, and placed in orbit in some five years. As it turns out, these capabilities (including 4-6 crew members, 15 kw of power, and a local space based transportation system -- an orbital maneuvering vehicle) would be substantially greater than those provided by the Soviet Union's present Salyut 7 infrastructure.

To date, no major space-related objectives have been called for that would require publicly-funded space infrastructure capabilities beyond those

required for meeting scientific needs. Furthermore, these capabilities could be augmented by the Shuttle Orbiter, the Orbiter-Spacelab combination, and free-flying platforms that could be available from our private sector (and perhaps abroad) by the end of this five-year period. **Therefore, requests for public funding of space infrastructure elements in excess of some $2 billion over the next five years should receive particularly careful scrutiny.**

It is particularly useful to note the specific words used by the President last week when he directed NASA to develop a "space station" and requested the Congress to authorize funds to begin the project. He did not say the "space station" -- he said a "space station;" he allowed a decade for its development; he invited the participation of other countries; and he saw an enormous potential for space commercialization. These criteria allow adequate time, and sufficient flexibility, for careful study of the most important uses to which any space infrastructure would be put; the kind needed; the amount needed, by when; how it should be procured; who should pay for it; and who should operate and use it. Most importantly, they allow time for a national debate and the setting of broad, agreed upon goals for space.

Mr. Chairman, it is also very important to appreciate that space infrastructure is simply that -- infrastructure. Its availability would allow certain space-related goals to be addressed and objectives to be accomplished. It would be a "stepping stone" to the achievement of objective ends. The President stressed this point by saying: "But most importantly ... a space station will not be an end in itself..." He stated that the country should reach for "... exciting goals in space ...".

The civilian space-related goals and objectives of the United States should be such as to command widespread attention; have great inherent humanitarian and scientific interest; foster the development of new

technology; have relevance to global issues; prompt international cooperation; and involve major participation of our private sector. But over the past decade the government has not studied and articulated such a national agenda of goals.

In the absence of long-range goals for the U.S. civilian space program, OTA concludes that it is simply not yet possible to judge, objectively, whether or not NASA's presently suggested infrastructure elements are truly appropriate and worth their substantial cost.

Parenthetically -- and OTA has been making this point for over a year -- we know of no broad and continuing professional study effort, the products of which could be used by our national leaders to see that the American public has the opportunity to consider and help adopt space-related goals and objectives that address important and long-term scientific, exploratory, and, especially, cultural, economic, social, and political ends.

The President has now taken a major step which raises the level of debate. His request for approval of another large and costly public space program should now prompt, indeed now require, a national debate about United States interests and purposes in the civilian space area. The situation in which our publicly supported civilian space program has been treated with a form of "benign neglect" can, and now should, be improved upon. The tangible and intangible results of our great investment in space has now positioned the United States to do almost anything it seriously wishes to do in and re space. There are many promising opportunities, and they could be realized with properly fashioned modern space policies, programs, organizations and institutional arrangements. What is now needed is not only, to use NASA's own expression in a recently issued contract to study of NASA's long-range goals,: "... the revitalization of the nation's space program ...", but also

to reach an understanding that the nation's civilian space interests are now broader than our government's space program.

Such a debate should be prompted not only by NASA's presently expressed aspirations but, as well, by military, other-country, and private-sector developments and considerations. All of these elements of our society, our universities, and particularly interested sectors of the general public should now move to participate in such a debate, and to explore ways by which broadened and more satisfactory cooperative arrangements among them could be fashioned.

Whatever the judgement of the Congress is re the Administration's request for approval and funds for detailed engineering design studies of space infrastructure over the next two years, this time certainly should be used by both Branches to see that the United States now decides upon and articulates again, in contemporary terms, its civilian space goals and objectives.

Finally, Mr. Chairman, as we now approach the considered development of space, we should be careful, above all else, that we not get caught up in either fascination with or the details of exotic space technology. What these times call for is not so much technical expertise, but vision, wisdom, judgment, and leadership. We should all now focus on sensible methods whereby we can indeed develop America's next frontier.

* * * * *

To recapitulate briefly, Mr. Chairman:

The energetic study, public discussion and, now, Presidential support of a "civilian space station" is serving a very useful purpose that transcends consideration of any station itself.

It is forcing us to re-examine our civilian space experience, institutions, and physical assets; our manner of acquiring, paying for and using these assets to provide useful services; and the influence of the space interests of other countries, and of our own private and military sectors, upon our publicly funded civilian space activities. We must re-examine our fundamental civilian space goals and objectives.

Today, we have far too fuzzy a vision. Without a clearer, more thoughtful, vision, how can we expect consensus on our goals? And without consensus, how can we rationally make long-term public commitments? Arriving at such a consensus should be our first order of business.

* * * * * * * *

Mr. Chairman, thank you for inviting us here today. I trust that the completed OTA assessment, which will speak directly to all of the matters I have mentioned here, will be useful to the Committee when it is available a few months ahead. And, in the meantime, we will continue to be in communication with you about them.

This completes our statement.

[Attachment]

The Attached Tables and Their Description are to Accompany the

Statement of T.P. Rogers, Project Director,

Accompanied by Dr. Philip P. Chandler, Deputy Director,

Civilian Space Stations Assessment

Science, Transportation, and Innovation Program

Office of Technology Assessment

Before the House Committee on

Science and Technology

Subcommittee on Space Science and Applications

Hearing re "Civilian Space Stations"

February 2, 1984

ALTERNATIVE APPROACHES FOR REALIZING SPACE INFRASTRUCTURE

The accompanying Tables are designed to assist in evaluating alternative approaches for obtaining space infrastructure that could, in varying degree, satisfy various needs or requirements that have been expressed for such infrastructure. The Tables include those elements of a so-called civilian space station as now generally envisioned in NASA planning.

Typical options (of the many that could be examined) are shown in Table 1 for three groups of possibilities. First, the present Shuttle Orbiter and its possible modifications for extended stays on orbit (Extended Duration Orbiter -- EDO) are listed. Second, one version of the Spacelab developed as a free-flying inhabited core vehicle is examined. Finally, the present NASA-envisioned space station concept is given: both the initial operational capability (IOC) version (~1992) and a mature, fully-developed infrastructure (~2000).

The parameters for each option that may be used for rough comparative purposes are:

1. Approximate date of availability, assuming that a "go-ahead" were given in 1985;
2. Cost (in FY 1984 dollars) to produce the capabilities shown. Some options depend on existing hardware so the costs do not reflect similar proportions of development and production efforts for the various options;
3. Characteristics -- several design parameters and sizing factors that provide the bases for infrastructure capabilities;
4. Capabilities -- the types of functional activities that the listed infrastructure should be capable of supporting, and the degree to which these activities might be accomplished;

5. Responsiveness of a given infrastructure to the various reasons put forward for having a "civilian space station," including any extended presence of human beings in space.

If great and long-range space activities (such as say, for instance, the establishment of a lunar human settlement or the return of materials from the asteroids or Mars) come under consideration, they would appear to be achievable using a sophisticated orbital transfer vehicle coupled with on-orbit assembly, check-out, launch, and recovery. The one option listed in Table 1 with some of these capabilities is the NASA fully developed infrastructure.

Table 2 presents information on proposed "free-flyer" space platforms that could be used in conjunction with, and serviced by, any of the options listed in Table 1. In this way, additional capabilities could be added to the infrastructures given in Table 1 for the cost of buying and incorporating these platforms in the overall infrastructure.

Interest within the private sector indicates that it may be able to provide some of the platform elements of a space infrastructure; in Table 2, both MESA and LEASECRAFT are proposals of United States aerospace companies (Boeing Aerospace Company and Fairchild Space Company, respectively). Among others, a new private enterprise, Space Industries, Inc., is studying a module that would be a long-duration industrial facility suitable for manufacturing (materials processing) in space. While it is too early for details of design and cost to have been revealed by the company, the module apparently would be tended by a crew while the Shuttle was in its vicinity. As with the others, it could be in place prior to the planned installation of the NASA-proposed space infrastructure. In addition, both Teledyne-Brown and Ball Aerospace Systems are studying the possibility of providing facilities that would be mounted in the Shuttle's cargo bay and used for experiments.

Another alternative not specifically listed in the tables is the use of the Shuttle external tank (ET) as an infrastructure component. Conceivably, the ET could be used for fuel and materials storage, as a pressurized module, for mechanical structure, and as a safe haven during emergencies. A principal advantage is the low in-orbit cost. Relative to the other alternatives, it has received modest study and is therefore mentioned here only.

Some cautions should be noted in the interpretation of this information. These are preliminary descriptions of the options and estimates of their capabilities. All estimates are given to an order of magnitude. Capabilities have been described by qualitative adjectives; quantitative descriptions would be premature at present. In the fifth section, in response to the reasons advanced for a space infrastructure, the comparisons are qualitative and subjective in nature and are presented simply to bring these factors to the attention of the reader. Future revision is possible as issues become more sharply focussed and designs are given more study. For instance, as a particular item the Spacelab option of Table 1 is only one of several that have been put forward; one by the European Space Agency (ESA) countries could definitely augment international cooperation if it were to be implemented.

Table 1
COMPARISON OF SOME OPTIONS FOR EARTH ORBIT INDEPENDENTLY OPERATING INFRASTRUCTURE

SYSTEM:	SHUTTLE ORBITER	EXTENDED DURATION ORBITER: PHASE I	EXTENDED DURATION ORBITER: PHRASE II	SPACELAB (DEVELOPED AS PERMANENT INFRASTRUCTURE)	NASA INFRASTRUCTURE ASPIRATIONS: INITIAL OPERATIONAL CAPABILITY	NASA INFRASTRUCTURE ASPIRATIONS: MATURE, FULLY DEVELOPED
Date available						
(Now, or approximate, assuming start in 1985)	now	1988	1990	1990	1992	1996-2000
Cost						
(Billions of FY 1984 dollars)	none	0.1	0.4	2	8	20
Characteristics						
Power to Users (kW)	7	7 (less if over full stay time)	20	6	90	200
Pressurized Volume (ft^3)	2000	2000	5000 (with Spacelab habitat)	5000	6000	10,000
Crew Size	6	3	5	3	8	20
Miscellaneous	can accept Spacelab	no new technology	new technology required; limited laboratory space	limited crew accommodations	orbital maneuvering vehicle plus two free-flying unpressurized platforms	reusable orbital transfer vehicle plus several more platforms
Capabilities						
Time on Orbit	10 days	20 days	30 days	unlimited (60-90 day resupply)	unlimited (90 day resupply)	unlimited (90 day resupply)
Laboratories for:						
Life Sciences	yes	yes	yes	yes	yes	yes
Space Science/Applications	very modest	very modest	very modest	limited	extensive	extensive
Materials Science	some	some	moderate	moderate	extensive	extensive
Technology Development	modest	modest	some	moderate	extensive	extensive
Observatories	no	limited	limited	limited	extensive	full
Data/Communication Node	no	no	no	no	yes	yes
Servicing of Satellites	modest	modest	modest	modest	extensive	full
Manufacturing Facility (materials processing)	no	no	limited	limited	extensive	full
Large Structure Assembly	no	no	no	limited	moderate	extensive
Transportation Node	no	no	no	no	moderate	extensive*
Fuel and Supply Depot	no	no	no	no	no	yes
Response to Reasons for Space Infrastructure						
Maintain US Space Leadership and Technology Capability	no	little	some	modest	considerable	extensive
Respond to USSR Space Activities	no	weak	weak	modest	strong	very strong
Enable Long-Term Human Presence in Space	no	little	modest	considerable	extensive	extensive
Attention-Getting Heroic Public Spectacle	no	weak	weak	modest	modest	modest
Extended International Cooperation	little	little	potentially moderate	potentially moderate	potentially considerable	potentially extensive
Promote US Commercialization of Space	little	modest	modest	indeterminate	indeterminate	indeterminate
Maintain Vigorous NASA Engineering Capability	no	negligible	negligible	little	extensive	extensive
Enhance National Security, Broadly Defined	no	negligible	negligible	little	indeterminate	indeterminate
ace Travel for Non-Technicians	little	little	little	little	some	some

* Incl. launch to moon, Mars, asteroid

Table 2
SPACE PLATFORMS THAT COULD BE SERVICED BY SHUTTLE
OR ANOTHER SPACE INFRASTRUCTURE ELEMENT, THE ORBITAL MANEUVERING VEHICLE

PLATFORM:	Unpressurized Coorbiting Platforms (serviced with extravehicular activity)				Pressurized Platform (serviced internally while docked)
	SPAS	MESA	LEASECRAFT	EURECA	EUROPEAN MODIFIED SPACELAB
Date Available					
(Now, or approximate assuming start in 1985)	now	now	1986	1987	1989
Cost					
(Billions of FY 1984 dollars)	0.005	0.01	0.2	0.2	0.6
Characteristics					
Power to Users (kW)	0.6	0.1	6	2	6
Pressurized Volume (ft^3)	none	none	none	none	3000
Crew Size	none	none	none	none	3
Miscellaneous	3000 lb payload	200 lb payload	10,000 lb payload	2000 lb payload	20,000 lb payload
Capabilities					
Time on Orbit	10 days	6 months	unlimited	6 months	unlimited
Laboratories for:					
Life Sciences	no	no	no	no	modest
Space Science/Applications	very limited	very limited	modest	modest	modest
Materials Science	very limited	no	modest	modest	moderate
Technology Development	no	no	little	little	modest
Observatories	no	no	modest	modest	moderate
Data/Communication Node	no	no	no	no	no
Servicing of Satellites	no	no	no	no	no
Manufacturing Facility (materials processing)	no	no	considerable	modest	considerable
Large Structure Assembly	no	no	no	no	no
Transportation Node (assembly, checkout and launch)	no	no	no	no	no
Fuel and Supply Depot	no	no	no	no	no
Response to Reasons for Space Infrastructure					
Maintain US Space Leadership and Technology Capability	no	no	no	no	no
Respond to USSR Space Activities	no	no	no	no	modest
Enable Long-Term Human Presence in Space	no	no	no	no	no
Attention-Getting Heroic Public Spectacle	no	no	no	no	no
Extended International Cooperation	yes	no	no	yes	yes
Promote US Commercialization of Space	indeterminate	yes	yes	indeterminate	indeterminate
Maintain Vigorous NASA Engineering Capability	no	no	no	no	no
Enhance National Security, Broadly Defined	no	no	no	no	no
Space Travel for Non-Technicians	no	no	no	no	no

Mr. VOLKMER. Thank you, Mr. Rogers.

Before proceeding with questions. I will now recognize the gentleman from New Mexico for his statement.

Mr. LUJAN. Thank you very much, Mr. Chairman. As you know, I, too, have been a strong supporter of the space station and was one of many who urged the President to approve it. One of the reasons for my enthusiasm is my belief that the future U.S. economic strength lies in America's innovative talents.

The space program has driven the technology development for new industries. Some of these have been directly space related, such as the boom in the communications industry, while others are more indirect, such as the stimulation the space program has provided for the computer industry.

Although these are the most obvious examples, it certainly makes my point. Much of the present areas of economic strength for the United States are offsprings of the space program.

The space station is the perfect vehicle to encourage such technology development in the future. Some of these possibilities are clear: the manufacturing of crystals for the semiconductor industry, the superlight and high strength materials, the further advances in communications, computers, space transportation, the development of robotics. These are all clearly areas of continuing and future economic strength for the United States.

But there are some intangible aspects to the space station that should be part of our perspective. One of these is the manufacturing of pharmaceuticals in space that would give new hope for victims of many diseases. I recognize that this also represents a good commercial area, but for a diabetic or the victim of a growth hormone deficiency, the possibility of a lifetime cure is not an economic matter. The development of the biomedical opportunities will benefit not just the diabetic in the United States, not just their families, but promises to benefit people throughout the world.

A second intangible type benefit is the scientific merit. I am aware of the caution of space scientists in supporting the space station. They may be justified in their reluctance since they saw their valuable funding resources diverted for the space shuttle development, but I believe the Shuttle is proving itself to be one of their, the space scientists' best assets now that it is operational. More important, I feel it is our responsibility to reassure space scientists that they will have our support for a strong program parallel with, not after, the development of the space station. We will have to see that these programs receive strong funding support and are not the victims of operational programs.

Finally, the space station is indeed, as many have said, the next logical step. It is important as a base for future exploration for the solar system, hopefully, manned missions to Mars and such futuristic ideas as colonies on the Moon or elsewhere in space.

I hope my fellow members will join me in my enthusiastic support for the space station. However, there is much work to be done yet by all of us for the exact nature of the space station, the role of U.S. industry and for other countries, the policies on access and pricing, the management approach, and many other issues still remain to be resolved. We can't afford to be uncritical supporters of the space station, but we also cannot afford not to be supporters.

I look forward to hearing from our witnesses this morning.

Thank you very much, Mr. Chairman.

Mr. VOLKMER. Thank you.

Mr. Rogers, could you provide the list of the advisory panel for the OTA study for the record?

Mr. ROGERS. I would be pleased to.

[The information follows:]

08/08/83

CIVILIAN SPACE STATIONS
ADVISORY PANEL

Mr. Robert A. Charpie, Chairman
President
Cabot Corporation
125 High Street
Boston, MA 02110
(617) 423-6000

The Honorable Daniel J. Boorstin
Librarian of Congress
Thomas Jefferson Building
Room 106
10 First Street, SE
Washington, DC 20540
(202) 287-5205

Dr. Harvey Brooks
Benjamin Peirce Professor of
Technology & Public Policy
Harvard University
Aiken Computation Lab - Rm 226
Cambridge, MA 02138
(617) 495-2831

Mr. Peter O. Crisp
President
Venrock, Inc.
Room 5600
30 Rockefeller Plaza
New York, NY 10012
(212) 246-4040

Dr. Freeman Dyson
Institute for Advanced Study
Olden Lane
Princeton, NJ 08540
(609) 734-8055

Mr. James B. Farley
Chairman of the Board
Booz-Allen-Hamilton
101 Park Avenue
New York, NY 10178
(212) 697-1900

Mr. Charles E. Fraser
Chairman
Sea Pines Company
Fraser Building
Hilton Head, SC 29928
(803) 785-3333

General Andrew J. Goodpaster
409 N. Fairfax Street
Alexandria, VA 22314
(703) 548-6532

Dr. Charles Hitch
The Lawrence-Berkeley Laboratory
University of California
Berkeley, CA 94720
(415) 486-4110

Dr. Bernard M.W. Knox
Director
Center for Hellenic Studies
3100 Whitehaven Street, N.W.
Washington, D.C. 20008
(202) 234-3738

Mrs. Moya Lear
Chairman of the Board
Lear Avia Corporation
P.O. Box 60000
Reno, Nevada 89506
(702) 747-6334

Dr. George E. Mueller, Jr.
President and Chief Executive
Officer
System Development Corporation
5151 Camino Ruiz
Camarillo, CA 93010
(805) 987-9311

Dr. Carl Sagan
Director of the Laboratories for
Planetary Studies
302 Space Science Building
Cornell University
Ithaca, NY 14853
(607) 256-4971

Dr. Eugene Skolnikoff
Director
Massachusetts Institute of Technology
Center for International Studies, E-386-648
2929 Main Street
Cambridge, MA 02139
(617) 253-3140

Dr. James Spilker
President
Stanford Telecommunications Inc.
1195 Bordeau Drive
Sunnyvale, CA 94086
(408) 734-5300

Dr. Frank Stanton
President Emeritus
CBS Inc.
10 East 56th Street
New York, NY 10022 8183
(212) 752-4445

Dr. James A. Van Allen
Head of the Physics & Astronomy
Department
University of Iowa
Iowa City, Iowa 52242
(319) 353-4531

Mr. VOLKMER. Thank you.

You mentioned in your statement also and in the papers that are attached to your statement an approximate $20 billion ultimate cost fully developed. That goes beyond what is presently envisioned by NASA as far as the time frame for an initial space station?

Mr. ROGERS. That is correct. My understanding is that their present estimate is for what they describe as an "initial operating capability" to be in hand within the decade, as the President said, some $8 billion. Earlier estimates that they provided to us said that by the end of the century perhaps $17 to $20.

Mr. VOLKMER. That is for additional platforms?

Mr. ROGERS. Additional capabilities, yes, sir.

Mr. VOLKMER. Now, in your statement also you said that NASA favors large, sophisticated ensemble of elements employing a great deal of new technology capable of supporting a human work crew and apparently favors procuring it in the classical NASA fashion. What do we mean by classical NASA fashion?

Mr. ROGERS. Essentially, it means that NASA would decide upon not only the functional characteristics, that is, what should be done, but also essentially the engineering characteristics of how to see that it is done. Then they would go out with a competitive procurement after going through a number of phases, and award contracts to a leading company or two to produce that hardware to their specifications—their detailed engineering specifications—and oversee the entire development and production and installation process in detail. That is what has been done on the shuttle program, the Apollo program. It is essentially the way that most of the large high technology development programs are carried out by NASA.

Mr. VOLKMER. What would you suggest as an alternative approach for doing it, if not at this time, in your final OTA study I would appreciate it.

Mr. ROGERS. We certainly will speak to that, Mr. Chairman, because it is clear that the President wants, and it makes a great deal of sense as well, to consider what other, accomplished countries could do, not simply in cooperation, but in collaboration with NASA, in order to be sure that we have a share of the benefits, that they take advantage of the professional capabilties there, and that we share the costs and therefore reduce the demand upon our own Federal budget.

Certainly, we have a great deal of reason to expect that within our own country, people will come forward from the private sector and offer to deliver assets and services to meet the performance specifications that NASA believes should be met and offer to do it, or at least parts of it, by developing it, the physical assets or the services themselves, producing them, paying for them, installing them, operating them. We observe that this is already happening in the expendable vehicle area, and we talked to a great many people around the country that suggest to us that within the next two years the likelihood of that happening is non-trivial, as a mathematician would put it.

I might say, in passing, that we have the first important contemporary example of that, not in the space station area, but in the satellite communications area, as you know.

Mr. VOLKMER. You would agree that NASA then should look in the development of the space station to working with international groups, ESA, Japan, Canada, and others as I understand they plan to do and also with the private sector here for development of it?

Mr. ROGERS. That is right. I do think, in fact I know, that NASA has consistently embraced the notion of working cooperatively with other countries and with our private sector. However, I think this now will take on new dimensions, absolutely new dimensions. The amount of cooperation and collaboration and the form that it will take is bound to have an important influence on the way that NASA itself does its own business.

Mr. VOLKMER. All right. My last question: how would you compare the capability of the space station that we now envision with the basic full components as I understand, the module type of system, with the capability of the most recent Soviet Salyut space station.

Mr. ROGERS. Well, they are far beyond what the Soviet Union has. Phil is a lot more familiar with that. Do you want to speak to that?

Dr. CHANDLER. I don't think so.

Mr. ROGERS. We would have many more people up there. We would have not only the centroid infrastructure outlay that is contained within the Salyut Seven envelope, but we would have local orbital maneuvering vehicles that would move back and forth with free flyers. We would have free flyers, platforms, in that orbit of the central element at other altitudes. We expect to have another one or two platforms elsewhere, perhaps in polar orbit. We expect to have the ability to march on out to synchronous orbit. A great deal more capacity, a great deal more power. We are talking about having 10 times the power available for the users that now Salyut has. So, there is a very, very great difference.

Mr. VOLKMER. You plan to have your full report on your assessment by approximately when?

Mr. ROGERS. Well, we are overwhelmed with success, Mr. Chairman, in one sense. We had been positioned to proceed in a certain fashion. Of course, the President's decision and his articulation thereof has changed our perspective to some considerable and, in our view, a very favorable respect. That will probably cost us an extra month and we are quite pleased to pay that cost. We hope to get it to you in April. Well, let's put it this way. We hope to be

finished in April. How we get it to you is beyond me. There are other considerations.

Mr. VOLKMER. Thank you very much. I now recognize the gentleman from Florida, Mr. MacKay.

Mr. MACKAY. Dr. Rogers, this is very refreshing. It seems to me that what you are saying is that before we choose between a stripped-down model A and a Cadillac, we ought to try to decide what the journey is going to be like and which one we need; or otherwise we are liable to buy more than we need, or we are liable to buy a vehicle that is inappropriate for the trip.

My question is, will your assessment include alternative visions of what the goal should be and the implications of those?

Mr. ROGERS. Before I am really drummed out of the space club by my close professional associates at NASA, might I say that our position is not that nothing should be done while we all think in great terms about the ultimate good of our society, but rather that they do what they are very good at doing and what they want to do, and that is to lay out in firm engineering detail what it is that these various components could really do and how they could do them and what they could be expected to cost. At the same time, we do have now the time and the flexibility and the prompting to think about, in broader terms than simply infrastructure, where this country might be going.

Yes, the answer is that we will do our best to put on the table a suggestion of some contemporary goals and objectives for the civilian space activities of this country.

Mr. MACKAY. Now, you have made that distinction throughout your paper, which I consider a very useful distinction: the civilian space activities of this country. You are not pretending that this is being driven solely by the civilian needs of the country, are you?

Mr. ROGERS. I am separating, attempting to separate, both the military and the civilian. The civilian in our country versus the civilian in other countries, and the publicly supported, Federally tax-revenue supplied activities from the private-sector activities. So, we are trying to choose our words as carefully as we can. In tne large, now, we should be thinking about the broader interests, the broader goals, the broader objectives of the whole Nation, and then have these various segments and sectors of the population take a hard look at it, in that envelope.

Mr. MACKAY. Your statement seems to imply that we have sort of run off the edge of the map in terms of the goals that we have for NASA. You are talking about a contemporary set of goals. That implies to me that what we are doing now exceeds whatever goals we have had. Is that your evaluation?

Mr. ROGERS. It is worthwhile recalling, and it is easy in this room to recall, that it wasn't very long ago that there were very few physical assets that were able to penetrate space, let alone human beings. Those were days when most of the hardware didn't understand the theory and we were all frightened. I can remember the day when the first man from the United States went up there, and we wondered would he have a heart attack in the absense of gravity and die.

In those days, then, therefore, there was a great scientific thrust: what are the characteristics of this space that we want to pene-

trate and learn to survive in and function in. A very conservative technological view to anticipate all combinations of difficulties and deal with them a priori. Those days are over now, Mr. MacKay. We have spent $200 billion to find out, in 1983 dollars, what is up there and how to deal with it. What we are now saying is that we should work on the basis of that investment's having successfully been made.

However, and I hope this is not misunderstood, my sense of the way that the country has been treating the civilian space program over the past decade or so is, to coin an old expression, with "benign neglect". The people of the United States have a great deal of interest, in general terms, in the space activities of the country. It has excited, at times, of particular events. It views with wonder the photographs taken back from distant worlds. It supplies enormous amounts of money, relatively. But it has very little to say about what we are doing, what we should do, and how it should reflect upon our everyday lives. It has very little to say about how this should be melded into the ongoing stream of interests and concerns of the general public.

So, who are making the decisions of what we are doing in space? People like me, scientists and engineers. I am both. Some of them are my good friends. However, we are rather limited in our view. Indeed, we think it time now, and indeed meet, and indeed required, that we step back and take a much broader view of where it is we could be going, and explore not simply scientific ends, not simply ends of exploration, but cultural, economic, political and social ends as we do in every other area of our national interests.

Does that help you?

Mr. MACKAY. Very, very much. Thank you.

Thank you, Mr. Chairman.

Mr. VOLKMER. The chair now recognizes the gentleman from New Jersey, Mr. Torricelli;

Mr. TORRICELLI. Thank you, Mr. Chairman.

Mr. Rogers, I wonder to this point, and not wanting to jeopardize your position in the space club, your confidence that at this point the managerial, technical, administrative talent remaining in NASA at this point in its history is adequate to undertake yet another new challenge. Are we in a position where we can feel comfortable? Are we in a position where we are going to have to look for a major strengthening of the apparatus in NASA?

Mr. ROGERS. The assessment is not looking at that, Mr. Torricelli; so I am able work my way through the crevice there. However, I think that two observations are in order. The first observation is that I have at least as much respect for the capability and the energy and the integrity of the people in NASA as I do in any other Federal department or agency. I have worked in senior positions elsewhere in the Government, so I have some basis for making that remark.

I also have the sense that the senior people within NASA now understand that, as Adam said to Eve upon leaving the Garden of Eden, "we are living in an age of transition." If they are given two things, I think they will do us all well. One, if they are given the encouragement to pull upon other sectors of our Nation then the scientists and the technician, not in place of but in addition to, to

pull upon other interests of the country, learn of what they could do to restructure, broaden the things which NASA is capable of doing to meet more of these interests, they will do it and they will do it well.

I think the other thing is that they could use that would be helpful to them would be for the Congress to suggest that they should feel encouraged to make these changes. Change, you know, is what the other person does. I think the Congress could be very helpful in the regard of encouraging them to take a real look at some of their programmatic ends and their management practices and their procurement practices and to be very outgoing in searching out novel ways for involving other countries and the private sector, and they will find this very complex and very difficult, and they will need your encouragement and your support.

Mr. TORRICELLI. Mr. Rogers, evaluating any proposal one looks to not just the modifications but their radical alternatives. If we did not embark on this concept of a permanent space presence, what else would have been an alternative? I am not talking about slight modifications, but is there another objective in space, the second choice, that in economic and scientific terms should be weighed or has been weighed against this concept, considering the concept in broad terms?

Mr. ROGERS. I would say two things in response to that. I think you might do well to ask NASA that, the President's Science Advisor that, some of the other leading officials in Washington: Is this indeed your considered judgment? Is this the next best major logical thing to do?

NASA has given you its judgment. They didn't get to this point lightly or quickly. They thought very, very hard and very, very long, and they have their own internal rationale and the external expressions of it.

Having said that, we are not in a position this morning to say what any other such objectives might be, but we will do our best and it is now our plan, by the time our report comes out, to try to prompt and broaden this debate, put some on the table and stimulate people to think in broader terms. Yes, we will try to do that.

Mr. TORICELLI. Let me ask this: at the time of the President's speech, different commentators and writers were raising the point that there is nothing that a manned station can do in permanent orbit that a nonmanned station can't do for significantly less money and greater safety. It is early in this process of evaluation to reach conclusions on that, but how, generally, do you react to that?

Mr. ROGERS. That view is simply incorrect, for two reasons. One, within the classical context of what we think could be done in space, there is an area called life sciences. Let's assume for the purpose of discussion this morning that our country's ambitions and actions will see us over the decades, have our people in space for very, very long periods of time and at distant locations. There are simply things in the physiological and psychological and the social domain that we don't know about today, that we would have to know about before our people could, with confidence, live that way. So, people must be studied in orbit and studied for long periods of time.

Now, you only need one exception to the rule, and that is one that I could give to you, that in the scientific domain, itself, there are basic scientific inquiries that need to take place that require people in orbit to be studied in orbit.

The matter of people working in space versus the matter of machines working in space has been a matter which has taken about as much of our attention as anything else, and I find that area to be describable more easily in terms of passion than of reason. Our own sense, from all that we can learn, is that of course the obvious is true, that you do both. You put people up there to deal with the unexpected. You put people up there to think in different terms. You put people up there to communicate rapidly, broadly, and under unusual conditions with people on the ground, as was done I understand quite effectively in the spacelab experiments of recent vintage. You put an automaton up there anytime that you think you know what you are going to do and expect to be doing it for a long period of time.

With time, the number of things that the machines can do will increase and the number of demands of certain kinds that you have to put upon human beings will decrease.

All this is fine if it weren't for the discussion immediately turning to about what costs the most. The only thing that I can say to that is that we ought to be thinking of ways to keep the costs as closely in hand as we can regardless of whether we use people or machines or, as is most likely the case, both, plus our emphasis on trying to keep the total cost down.

Could I add one more thing——

Mr. TORRICELLI. It seems the timer is broken. I think that means that I can ask questions endlessly. [Laughter.]

Am I out of time, Mr. Chairman?

Mr. VOLKMER. Go ahead.

Mr. TORRICELLI. Thank you.

Mr. ROGERS. Could I add one embellishment to my remarks?

All of the discussions about whether or not we should have people in space or machines in space takes place without our thinking about it in terms of work. Now, we are working here this morning. I am, anyway. That is not all we do. In fact, in our culture, in an odd day, it is not even the most of the things we do. We do a lot of other things that we could be doing in space in a completely different context.

We hear of space being talked about in terms of turning the wrenches and looking through scopes. We don't hear of space in which a person learns to choreograph a ballet in the absence of gravity or to put poets up there to take an entirely different view of the universe or to have religious experiences in the absence of everything else in the great quiet of space. We don't think of space as a place where sports could be conducted, with all the gloves off, all the rules off, in an infinite playing ground.

Work, we are talking about. If you ask the question, not what is the role of a human being or a machine in space, but ask the question should we send a machine into space or me? It changes it completely. I think that is a broader way of looking at it.

Mr. TORRICELLI. Thank you.

Mr. VOLKMER. Just to go on a little bit, will the OTA assessment assess what can be done in space and what, if we are looking to the future, what our goals are as to the use of unmanned space stations, free flyers, et cetera, and the limits of those and what they can do as opposed to a manned presence in space, because, as I understand it, there are proponents who feel that we do not need a manned presence but there are those also who point out that without a manned presence, you are limited as to what you can do also.

Mr. ROGERS. Yes, Mr. Chairman.

Mr. VOLKMER. Will your assessment speak to that?

Mr. ROGERS. Yes, that is correct.

I would say, in passing, that at one of our workshops, Phil obtained the attendance of some very senior Japanese professionals. Of course, their being there prompted us to raise the questions of the people judged to have at least as much experience in this area as anybody else. In fact, because of the language difficulties, we asked the question twice to be absolutely sure. Their answer was essentially as I gave it, that when you know what your are going to do and when you are going to be doing it, and so forth, but before that, you had best use your head.

Mr. VOLKMER. Thank you.

I now recognize the gentleman from New Mexico, Mr. Lujan.

Mr. LUJAN. Thank you very much, Mr. Rogers. It is certainly most interesting. Five minutes is hardly enough time to discuss such a fascinating question as the whole question of the space station. I will get seven, I understand. I just talked myself into two more.

Your closing statement says we have too fuzzy a vision. I gathered from that that you felt we weren't ready. As a matter of fact, I guess that is exactly what Mr. Beggs was saying yesterday when I asked him what we would use that original $150 million dollars that the President is proposing now. He said that would probably be to look at such things as design, materials, the uses, the needs, nothing is going to start happening until perhaps 1987 or somewhere in there.

You are both saying the same things except that he is saying, let's put $150 million up in order to start finding out the information, in order to make that decision.

Mr. ROGERS. What we are saying is that it is NASA's judgment, based upon their experience with past major high technology programs, that they are determined this time to take enough time and care and detailed study attention to be sure that they really know where they are going and why—in an engineering, an engineering sense.

What we are saying is that, in parallel with that Mr. Beggs and his colleagues ought to be prompted to do two things. One, to try to broaden their sense of the goals and the objectives that this country could aspire to, and also to look as well at how they can better collaborate, and I use that word particularly, it is much more than cooperate, but to collaborate with our other friendly countries—in fact, to a first approximation, every other country of the world.

Mr. LUJAN. But, he was saying that same thing yesterday.

Mr. ROGERS. Well, we might ask what fraction of the $150 million will go on to these other broader things than engineering

things. If you want to know what is going on in a bureaucracy, you mustn't pay too much attention to what people say or to organization charts; you look at where the money flows. So, you might ask him about that.

Mr. LUJAN. OK.

I am interested in how we can build a space station for $5 billion instead of $20. That always interests me particularly. What sort of things do you take into consideration in both projections? The amount that Government is going to put in? We are looking for some sort of alliance with, as you mentioned, foreign countries, private industry. Do you put in the operational costs? Do you include in that $20 billion the costs of the shuttle? Then, as far as the $5 billion is concerned, what do you put in there?

My general impression is that I hope $20 billion is too high a figure and that we would come in at less than that, but that $5 billion might be a little low in view of the fact that just one item, just the power source, with developmental costs and getting there, would probably be somewhere about $1 billion perhaps, hopefully not $2 billion. Who knows where that figure is going to go.

What are the differences that you are putting in that account for the $15 billion difference?

Mr. ROGERS. In the first place, we are only talking about initial capital costs. We are not talking about any so-called O&M, ongoing operations and maintenance.

Mr. LUJAN. In both instances?

Mr. ROGERS. In all instances, yes.

Mr. LUJAN. The $20 billion and the $5 billion?

Mr. ROGERS. Yes. In all cases also we are talking of the capital cost of the infrastructure itself alone. We are not talking about the additional cost required for equipments, sensors, experiments to be conducted. So, those are two very basic points.

We are talking now about total capital costs estimated on the basis of the present way of obtaining them, and, at the moment, all of these costs are being thought of as United States, publicly-funded costs.

I think that the NASA people probably made pretty good—I think it is probably low, but I think it is a good, good judgment. We can debate about it, but what we are saying is that within that total cost, the question should be asked, who pays how much? We think there are two very important areas to be looked to for additional funding for which there must be a quid pro quo, and that is having other countries work with the United States and the other is to have our private sector step up to the bar and offer to provide parts of this infrastructure to meet the NASA specifications, but with them funding a good part of it and also at lower cost.

Mr. LUJAN. So, in sum, what you are saying is that the $5 billion represents the fact that we already have the materials, we have the engineering capability. It is just the cost of putting the building together and that the $20 billion, since they are looking at new materials, new methods—included in that is that you are subtracting from the cost to arrive at your $5 billion what others might put into it—so, you are saying that the development of new materials is included in that $20 billion, new methods, and you have not de-

ducted what other countries might put in and what private enterprise might.

Mr. ROGERS. We said a figure of $2 billion, I believe. In my testimony I mentioned $2 billion, Mr. Lujan.

Mr. LUJAN. I am sorry, yes, $2 billion.

Mr. ROGERS. We can arrive at a number like that, and we do, on the basis that we take the maximum use of presently in-hand, space-tested technology. We make as few modifications to it as is reasonably possible, and we get very tough minded about the acquisition process. We use the best ways—you talk about performance specifications rather than detailed engineering specifications—and we put the burden on the industry and upon other countries to step forward and say how they would do it and demonstrate that they would do it and they are people of integrity and they have a good track record and that it could be done.

The other thing that is very important is that would give a capability that is much smaller than what NASA has in mind, even for the initial operating capability under the total capability. What we are saying is that there is a very firm basis in science and in satellite servicing that could be met with about that kind or that cost of infrastructure obtained in that way.

Mr. LUJAN. Very good. That is a very good input to the debate and we will take it up with NASA when they come up. I love the $2 billion even better than I love the $5 billion that I was mistaken on.

Thank you.

Mr. VOLKMER. Thank you.

The Chair now recognizes the gentleman from Texas, Mr. Andrews.

Mr. ANDREWS. Thank you, Mr. Chairman.

I guess I would like to ask you to go back and expand a little bit on some of your earlier comments about, for the use of a better word, drawing a consensus on what our long-range goals should be. Certainly, we have heard that kind of testimony before this subcommittee in this year, not only from NASA people but former NASA people, of the need to be more visionary in our scope.

I would like to ask you to be more specific in what kind of vehicle or plan do we need to get to the long-range plan, and how can we be more specific about specific steps that need to be taken?

Mr. ROGERS. Mr. Andrews, I am going to use a military expression at this moment. When I came to this position as a consultant to OTA for this assessment, one of the first things I did was to look about the country to try to identify people who really are professional workmen in this area. I found nobody. I mean, literally, nobody. So the military expression is that we not only have the problem, that we don't have an agenda of agreed-upon, consensual goals and objectives, but nobody is working the problem. Nobody is working the problem.

We bring this out again in our testimony this morning. I and others at OTA over the past year or more have said that we just do not have people in this country who are working on policy related space problems. That, I think, is a sad and important omission.

Now, as to what should be done about it: The most important thing that anybody could imagine having done was done last week.

The President of the United States devoted one quarter, after the preamble, of his speech to the space area. A very small fraction of it, by the way, to the space station. He devoted an entire speech on the radio on Saturday, last Saturday, which had a number of very important points. I might say in passing that whoever has been giving him advice and helping to craft those speeches has done the country a great service. Fine, fine pieces of paper.

The debate, now, that we have needed will start. You see, the President made a speech, he has made two or three speeches on the space area, one when the shuttle came back, one here in Washington. But, the debate didn't start. Well, it has started now, and it is right here in this room, because now he has committed himself by directing NASA to develop a Space Station, and he is asking for law and dollars. The debate is started. What we find in our office is that, at the moment, it is almost impossible to get our in-house writing work done because of the neccessity to respond to people in the press, radio, television, all of whom are interested in this matter of where now are we going, what should we be doing.

I would say the following two things, then, in summary. Just what is going on this morning in this room is what is required. When you see discussions of the space program not so much in Aviation Week and not in the IEEE Spectrum, but on the editorial page of the New York Times and the front page of the Washington Post and the editorial page of the Christian Science Monitor and the Los Angeles Times and so on, we have come a long way.

We will do our best, in the OTA assessment, to further that debate by putting on the table a suggested agenda of goals and objectives, and I would hope that the country will take this as an opportunity to pick it up and run with it.

Mr. ANDREWS. There is no question that it takes a President to set our country's agenda, and certainly in an area like space, there must be a President leading the way in phrasing and defining what our goals should be for the American people and for Congress. I can say the great majority of the members of this subcommittee have been for a space station for a long time, but that will not become a reality until a President puts his shoulder behind the boulder.

However, let me phrase it another way: what specific political and social goals should we be talking about that we are not talking now? You mentioned a list of social and cultural and political—

Mr. ROGERS. Yes. I feel a little bit uncomfortable, Mr. Andrews, because we are working that problem as hard as we can, and I am not in a position to speak to that beyond that at this moment. I simply cannot get ahead of the system and our advisory panel and so on. However, we will, within the next few months, come back to you with what we think should be seriously considered. That is the best that I can do this morning.

Mr. ANDREWS. Yes, that is the hard part. All of us talk about the need to be more visionary. I do it. Every Member of Congress does it, especially as it relates to the space program. We had excellent hearings here in January about where we go in the future in the space program, but the hard boards of specifics are kind of hard to nail down. I am anxious to see what——

Mr. ROGERS. I agree with you completely. We are going to try some of those. We are also going to try, please God, to talk about another fascinating subject and that is how to pay for it.

Mr. MACKAY. That was the question. Would the gentleman yield? That was the question.

The other thing that was intriguiging about the President's speech was the way it epitomized the dilemma that our country faces. It started out talking about the need to balance the budget and then, with no transition whatsoever, launched us into massive new programs, costwise. I was going to ask, as part of your assessment, could you indicate to us ways in which the financing of it might be dealt with?

Mr. ROGERS. We will deal with that area. I don't want to make promises that we have stumbled upon the Holy Grail, but we will deal with that area, yes.

Mr. MACKAY. Thank you.

Mr. ANDREWS. Thank you, Mr. Chairman.

Mr. VOLKMER. The chair recognizes the gentleman from Virginia, Mr. Bateman.

Mr. BATEMAN. Thank you very much, Mr. Chairman. I am going to withhold any questions, just having arrived, until I get a little more of the flavor of what has been said and then, perhaps, I will have another go at it.

Mr. LUJAN. If the gentleman would yield——

Mr. BATEMAN. I would be happy to yield.

Mr. LUJAN. I just wanted to make one comment that we don't want to balance the budget on the back of the space program.

Mr. MACKAY. On the other hand, we don't want or need new frontiers paid for by our grandchildren.

Mr. LUJAN. Nor will we be able to.

Mr. ROGERS. Now I see what the average value is here.

Mr. VOLKMER. I would like to ask a couple more questions.

In your statement, you mentioned, to paraphrase, that any proposals that would exceed $2 billion spending in the next 5 years, and the next 5 years should be looked at with maybe a jaundiced eye or very carefully. Are you then proposing that we be able to have a space station concept for S2 billion? That is my question.

Mr. ROGERS. We are not looking at the larger numbers with a jaundiced eye, nor are we suggesting that you do that, Mr. Chairman. What we are saying is the following: we have attached to our statement an ensemble, an agenda of possible infrastructure arrangements and they range from the minuscule cost, minuscule capability to being able to do almost anything that people can imagine.

Now, in talking with people on the staff here, they said fine, that is very, very helpful, but could you give us a for-instance. Just give us one sort of marker point or reference point. What we did was to ask ourselves, what are those things that would go on in and re space that are clearly would clearly have very hard support, very tough support. That is research work that would require the infrastructure.

Our further judgment is that the servicing of spacecraft will probably get hard support.

So, we said, what kind of capability would you need to do those things? Then, if you said, let's forget about new technology or classical procurement measures or going it the United States alone or paying for it all out of Federal funds, how could you take another look at this and get the cost to the Government down? That is how the $2 billion came out. However, I would repeat, a smaller capability, and it requires a different way of looking at how we would get the technology. It is just a marking point.

Mr. VOLKMER. But you are not saying a total of $2 billion, but you are saying $2 billion out of Federal funds.

Mr. ROGERS. With some caution, with other countries.

Mr. VOLKMER. Do you mean within the $2 billion? Or do you mean above the $2 billion? That is what I am trying to get at. Is anything that we could get out of private enterprise in this country and internationally in addition?

Mr. ROGERS. Well, we use the word "some" $2 billion and that is as close as we can come.

Mr. VOLKMER. Do you plan to elaborate on that in your final assessment?

Mr. ROGERS. Well, I don't know that we are going to be able to do that very well for the primary reason that there are many things which people from other countries and the private sector people in the aerospace industry today and people getting into the space business today will tell us in confidence which we find it very difficult to put out in the public literature. To hear anything at all of this kind, we have to promise that their interests will be protected. This, I think, is our best judgment. I don't think we could go much beyond that.

Mr. VOLKMER. All right. Thank you.

Does any other member have anything further?

Mr. TORRICELLI. Mr. Chairman?

Mr. VOLKMER. Yes.

Mr. TORRICELLI. One final question, if I might. There are many American corporations who have gone into joint ventures with some of our economic competitors and have lived to regret it, being later devoured by the use of their own technologies that they paid for and developed. We are at that point as a nation. We can get into joint ventures with other countries, other countries who have not had to pay for the development of some of this technology, and we have, and give them the benefit of it.

Do you intend to deal with or do you have a thought now on whether, in fact, more to teach than we have to learn and whether since, some of us—I, for one—would approve and vote for such a station because of its economic benefits to the United States, whether in fact for the American taxpayers investments we are going to be giving economic benefits to others that we are going to see back in products competing with ourselves?

That is, maybe, an unfortunate way to have to look at the program, but if it is being justified in economic terms, it is one we had better consider.

Mr. ROGERS. Well, I will make two comments to that, Mr. Torricelli. One is that there are a lot of smart people in the world that don't reside in the United States and they are getting smarter all the time——

Mr. TORRICELLI. That is what led to my question.

Mr. ROGERS. And we were talking with some of them at one time, and a man, a former senior NASA official afterwards said to us, you know, what they have been saying is, "Gee, we came to the United States to learn a lot, and we certainly have learned a lot and NASA has taught us. And what they have taught us is that we are not going to do it that way." I think that, in the long run, and in general, it is a very healthy thing.

The second thing I would say is that, if we have our wits about us, all of the moneys that are saved by not being expended on the things which other countries now can do and which our private sector can do, those moneys should be given a great consideration on the part of the Congress to be fed back to NASA to be out further, out further in front, the more close to the cutting edge, more exotic. That is, I think, the posture that makes us—From our judgment, you have got to just stay ahead, stay ahead. I think that is an excellent way of deciding how much of NASA's money should go into the procuring of infrastructure: if there are other people that can do it, let's have them do it, and let us get on to the next big thing.

Mr. TORRICELLI. Is there a point in this process of decisionmaking, though, that someone deals with the economic realities of this, that as American industries, the so-called sunset industries keep sinking lower and lower, the space program has been an important part of developing new industries, and it has been good for us. It would also be good for a lot of other people. Is someone going to deal with the economic realities of what this might mean to some American corporations?

Mr. ROGERS. I certainly trust so. I know that the industrial leaders that we talked to have this very clearly in mind and weren't born yesterday. They are tough minded, and they are dealing with equally not-born-yesterday, tough minded people abroad. We just have to see how it falls out.

I would say one more thing about that, Mr. Torricelli. That is that, in my experience, the Congress has been a lot smarter about this than the Executive Office of the President.

Mr. TORRICELLI. That doesn't surprise me a bit.

Mr. ROGERS. I have seen a number of occasions where the Congress has done the obvious, just done the obvious. I am not about to go beyond that, but my particular field for years, for instance, was in satellite communications. We have nearly "given away the farm" a couple of times. I don't know why. I am not privy to the innermost councils of those decisionmaking offices. However, NASA has, for instance, in that area had an excellent relationship with industry, spent years building it up and working with them. As a consequence, the satellite communications commercial and industrial activities of this country are things we are all proud of. I can see only great success, the only great economic return that we have so far received on our investment in all of our expenditures in space. I think we have an excellent record of dealing with foreign competition. If we have our wits about us, we will continue that way, but when I looked at the budget yesterday, I was thin-lipped for a moment to see that plans for satellite communications activities of NASA have been given a wrench.

This is not the purpose of this hearing, as you know.

Mr. TORRICELLI. Thank you.

Thank you, Mr. Chairman.

Mr. VOLKMER. Any other questions any members may have may be submitted in writing, and we would appreciate your responding within a week or so.

Mr. ROGERS. Thank you very much.

Mr. VOLKMER. Thank you very much, Mr. Rogers, and Mr. Chandler. We appreciate your being here today. You have been very informative, and we look forward to the final report on the assessment by the 1st of May. I am sure that will still be timely. We have a long way to go on this whole process, yet.

Our next witnesses will be Mr. Philip Culbertson, the Associate Deputy Administrator of NASA, accompanied by Mr. John D. Hodge, Director of the Space Station Task Force.

Mr. VOLKMER. I welcome you here today, and you may proceed with your testimony, Mr. Culbertson. Before you begin, I would just like to say, if I get up and leave during the midst of your testimony, it is not because I am not interested. It is because I have another subcommittee which I have to attend in a few minutes. I hope to be back during the questioning period.

At this time, you may proceed with your statement. You may either review it in total or summarize it, however you desire. Your statement, along with Mr. Rogers', will be made a part of the record.

STATEMENT OF PHILIP E. CULBERTSON, ASSOCIATE DEPUTY ADMINISTRATOR, NASA, ACCOMPANIED BY JOHN D. HODGE, DIRECTOR, SPACE STATION TASK FORCE; AND ROBERT FREITAG, DEPUTY DIRECTOR, SPACE STATION TASK FORCE

Mr. CULBERTSON. Thank you, Mr. Chairman. I fully appreciate the fact that you are a busy man this morning, and I am sure we will come back to see you a number of times before this is all over anyhow.

It is a pleasure to be here this morning to discuss NASA's first request for a space station. With me, in addition to John Hodge, who has been the director of the Space Station Task Force, is Bob Freitag, who has been his deputy for the last year-and-a-half. The two of them together were leading essentially all of the effort that NASA has put in leading to the point where we find ourselves today. Both John and I, with your permission, will make a few comments today. We do not intend to read our statements—they are rather lengthy—but rather to summarize and make a few points of our own. We would appreciate if the statements did appear in the record.

Mr. VOLKMER. They will. They will appear in the record.

Mr. CULBERTSON. John and I, in talking about how to discuss this subject this morning, have decided that I will give a little bit of the background and the "why" of the space station, and he will give the "what" and the "how" as we stand today.

I must confess also that I am highly motivated to respond to a few comments that Mr. Rogers had, my good friend, Tom, and if I am allowed that privilege, I would like that, too.

Mr. VOLKMER. You may.

Mr. MACKAY. I assure you, you will get that chance.

Mr. CULBERTSON. I am not going to belabor the history of space station considerations, but I just wanted to bring up a couple of highlights that it seemed to me were interesting.

I go first back to 1869, when Edward Hale wrote in the Atlantic Monthly an article which he called The Brick Moon. He proposed a 60-meter diameter satellite, made of bricks and housing a crew of 37. From a 6,000 kilometer orbit, the brick moon would serve as a navigation aid for ships, communications were to be by morse code, with signals created by the station's occupants jumping up and down on the satellite's exterior surface. Thus, civilized man has studied space stations for a long time. We have made some progress in this study. In 1923, Oberth, who had many major contributions—rocketry, in a book which was entitled, "The Rocket Into Interplanetary Space," first described an orbiting satellite as a space station and proposed that it could be used as an observation site, world communications link, weather satellite, or as an orbital refueling station for outward-bound space vehicles. He added a few more objectives to that which had been proposed by Mr. Hale.

Then in 1952, Dr. von Braun, as part of a series of articles that appeared in the Collier's magazine, first talked more seriously about what present technology or technology at that time might yield in the way of a space station. His was 250-foot wide, a wheel-shaped section revolving in order to provide artificial gravity, and it would have been 1,000 miles up. This was, I think, the first series of articles in this country which awakened the American public to the possibility of space flight. In 1960, George Low, commenting in a meeting on NASA's future planning, presented a scheme with a manned lunar landing and the creation of a space station were given equal treatment as long-range goals of the NASA program. He said in this conference that we should develop an advanced manned spacecraft which could lead toward manned landings on the moons and the planets and toward a permanent manned space station.

Well, we know we decided to go on to the moon from that. But in the mid-sixties there was a study, the so-called manned orbital research laboratory, which went to some length in examining the possible uses of a manned orbital system and what it's configuration might be. It had abandoned the idea or we had gone beyond the idea at that time that permanent artificial gravity was necessary, and this was now an inertially stabilized vehicle with an onboard centrifuge, to face the possibility of the need for conditioning of the crew.

Later on, the Air Force began a program which they called MOL, the manned orbital laboratory, which was to be a 30-day vehicle, and in mid-1966, NASA was working on the so-called Apollo applications program in which we proposed that it was timely that we could update our studies of a permanent manned space station. There was a significant effort in the mid-1960s, led by Charlie Donlan, E. Z. Gray, and Chuck Matthews, and we moved one step further in trying to understand what kind of characteristics the system might have. Its needs expressed at that time, interestingly

enough, do not differ dramatically from the needs and uses that we see today.

However, one significant addition has come to light and is being given a great deal of attention and was one of the keystone's of the President's speech a week ago. That was that we are now greatly conscious of the possibilities of the private sector involvement in space, and that will be a key feature which we carry through all of our considerations of the space station, both in the development of the systems that might be possible to be part of the space station or at least contributory to the objectives of the space station but also in its use.

In a meeting in 1969, and in meetings throughout the next 3 years, there was a lot of discussion about the relationship of the space shuttle and the space station. There was early debate about whether or not we ought to develop a space station or a space shuttle first. As a matter of fact, they were considered in our overall planning as sort of a matched pair: the space shuttle to get us to space, and the space station to operate in space. The decision was reached that it was not appropriate to try to develop both at the same time and that we would proceed with the space shuttle as the transportation system and add the space station later.

Finally then, in 1973, there were continued discussions of a space station, and the results of that then were finally put on the shelf and we are now bringing them off the shelf. That is a very quick walk-through of a little over 100 years of history, but I wanted to emphasize the point that it is not a new idea.

So one must ask, "Why now? It never got started before. Why now?" There were three factors that were in the minds of Mr. Beggs and Dr. Mark during their confirmation hearings. They said that the next major initiative should be a manned space station or a permanent presence in space. One was the approaching operational status of the shuttle, which was early considered a necessary precursor to the space station. The second one was the growing interest of the private sector in assisting to develop the infrastructure but, more importantly, to use that infrastructure for commercial purposes. And finally, the growing interest of the international community, in collaboration with the United States and specifically with us in the space program and the manned side of that space program. These are the three things which were in their mind when they said that they felt it was appropriate as the next initiative, and in fact these are three of the significant elements that I believe were in the mind of the President when he made his decision to direct us to proceed with the development.

Our present thinking of the space station—and it is a conceptual thinking, because we have tried to explain every place we sat down, that the model you see on my left is a model of a concept only. We do not at this time represent it as the thing which will be built, because that is the purpose of our asking for money for the next 2 years' study. We need, as Tom Rogers pointed out, to more thoroughly examine the characteristics that the system ought to have, the relationship of that system with the broader long-range goals in space, and then the technology that is necessary for us to understand how to build it and to design it, and finally to schedule it and price it. We found that to describe all that without some-

thing physical to look at resulted in an awful lot of arm waving, and that is why we built the model.

Mr. Beggs yesterday told you of the seven or eight principal objectives or characteristics which we thought a space station should have, or at least the things that it should be able to do. I am not going to elaborate on them, except to run through them by name.

It is our present perception that the space station should serve as an on-orbit laboratory, as a manufacturing facility, as a servicing facility to unmanned systems, as a site for permanent observatories, and perhaps more importantly, as a site for the research necessary to know what to put into those permanent observatories, as a transportation staging node to get to geosynchronous orbit and beyond, as an assembly facility to build the larger things that we are convinced are inevitably coming downstream, many of which have already been proposed, and finally as a storage depot so that, in shuttle flights, when we have more capacity on a particular day than payload to complete that capacity, we can effectively utilize the capability of the shuttle to transport goods and materials to the space station and use the space station as a storage depot for spare parts or consumables or even standby satellites for on-call deployment.

Looking at the space station from a somewhat different direction than those specific functions, it is clear that it will continue to provide a stimulus to national research and advanced technology that has been a hallmark of the space program, that it will provide an excellent mechanism for international cooperation. Mr. Beggs pointed out that he has been directed by the President to take a trip to those countries which have indicated an interest in working with us and to be observant and learn what their interest might be and start then the process of formulating the details of how we might work on an internationally collaborative basis. The space station will, we believe, also provide the stepping stone for a broad range of potential space endeavors for the years to follow, which we cannot identify yet, as Mr. Rogers points out, because our relatively fuzzy view of the year 2000 and beyond, but which may become more clear as we engage in a debate.

No one function or capability alone could justify the development of a space station, not any of the single things that I referred to earlier—just as one mission would not justify the development of a new launch vehicle, or, in more prosaic terms, an occasional trip to the grocery store justify the purchase of a new automobile. Only when viewed in the aggregate is it appropriate for us to contemplate the development of a major system.

As we look at the National Aeronautics and Space Act of 1958, on which practically everything NASA does is based, it is interesting to examine the particular charges or the particular areas in which the responsibilities of the civil space program relate to what we might propose to do in a space station. I know all of you know this by heart, but I want to point out a couple of things.

It says that the aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives. * * * The second of those is the improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles. The third is the devel-

opment and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space. The fifth is the preservation of the role of the United States as leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere. And the seventh is cooperation by the United States with other nations and groups of nations in work done pursuant to this act and in the peaceful application of the results thereof. We believe that the space station fits all of those and that the space station effectively satisfied elements of all of those.

Before I ask John to briefly describe the studies which have led to the point at which we find ourselves today and to talk about the way we think we can proceed, I would like to make two other observations. The first is, if I may quote three people who I believe have had a unique insight into this Nation's space program. The first was Wernher von Braun in that Collier's article that I mentioned. He said:

> Development of the space station is as inevitable as the rising sun. Man has already poked his nose into space, and he is not likely to pull it back.

Eight years later, on May 8, 1961, 3 days following Al Sheppard's suborbital flight, James Webb, then Administrator of NASA, wrote to the Vice President, and in that letter he included the following statement:

> The orbiting of machines is not the same as the orbiting or landing of man. It is man, not merely machines, in space that captures the imagination of the world.

Finally, I would like to quote from a letter which I received from a parent who lives in Bayonne, N.J. It was dated December 18, 1983. The letter said:

> My son, Danny, is 11 years old and in the sixth grade. He is an honor roll student, with A's in math, science, and computer class. He always wanted to be a NASA engineer and astronaut when he grows up. I hope that you, sir, will do all within the power of your office to insure that when he does grow up, there will be a NASA for him to apply to.

Then on a somewhat more personal note:

> My 7 year old grandson knows the names of the shuttle crews and almost as much as I do about their mission objectives. He and his young friends have inundated me with their pictures of the shuttle and, more recently, their versions of a space station. These are the young minds we are stimulating, and these are the minds that will one day lead this Nation's industry, academia and, yes, the Government. The space station is not unique, but it will surely be a major contributor to this stimulation.

Now, if I may make a couple of comments on Mr. Rogers' interesting discussion this morning, the first, I guess, would be that near the close he said OTA will encourage that national debate about the goals of the space program, and he said that debate has probably started this morning. I would agree, that debate did start this morning. In a lot of respects, Tom and I agree on what he said. But there are some things about what he said that do bother me.

He said that NASA favors a large and sophisticated ensemble of elements employing a great deal of new technology and apparently favors procuring it in the classical NASA fashion. That classical NASA fashion has led to 1,000 collaborative arrangements with foreign governments and foreign entities in cooperative or collaborative programs in space, which has, it seems to me, been a major

factor in understanding and working with the international community. That classical fashion has also, more recently, led to a great number of working arrangements we have with the private sector, both to assist where we can in the stimulation of their interest in the use of space and, in many cases now, to the private-sector investments in part of the infrastructure. We, too, agree that is terribly important.

However, we are the stewards of an element of the Federal Government's activities in space. I do not know that it will ever be possible for us to remove ourselves in the procurement cycle as far as Mr. Rogers successfully might. I do think there are things we can do to improve the procurement cycle. There are some things that NASA can do, some things that can be done on a Federal basis, and I agree they should be examined. It does take too long for the Government to move and to get things done.

He pointed out that in the program we are discussing today, NASA has given you its judgment. I would rephrase it and say that the President has given you his judgment, and NASA is here to try and interpret that to you.

He talks about a $2 billion system, using today's technology and having fairly limited capability. But at the same time, he refers to the civilian space-related goals, such as to command widespread attention, to consider the inherent humanitarian and scientific interest, and to foster the development of new technology, to have a relevance to global issues. I do not believe that is the $2 billion space station that he defined. He then said that, accordingly, the cost could be as low as $5 million for the smallest unmanned platform or as high as hundreds of millions of dollars for a shuttle orbiter modified to allow an extended lifetime in orbit. Let me assure you, Mr. Chairman, that this is not the space station that the President defined or the one that NASA will attempt to interpret to you.

One final comment would be that in his paper he writes, "To date, no major space-related objectives have been called for that would require publicly-funded space infrastructure capabilities beyond those required for meeting scientific needs." I would point out, Mr. Chairman, that although NASA is a steward of much of space science, and I believe that our budget that Mr. Beggs discussed yesterday shows our commitment to that stewardship, nevertheless, when we consider a space station, we must consider more than meeting pure scientific requirements. That is the kind of space station that we have in mind.

With that, I would like to turn it over to John Hodge for his discussion on the past few months and the immediate time ahead of us. Thank you.

Mr. MACKAY. Thank you, Mr. Culbertson.

Mr. HODGE. It is indeed a pleasure to be here today. It hardly seems 7 or 8 months since we last talked; but, it was, indeed, August when we had significant discussions about what our planning activity was and how the task force was operating. The plans that I gave you at that time, in fact, we carried them out as we suggested we have done quite a bit since then. I would like to talk to some of those things and then discuss the project.

In parallel with the task force, you will recall we had a technology steering committee, and that committee has met several times

since last summer. We now have a long list of technology options which we need to apply to our studies as we start to go into the design phase of the program. That group was supported by all of the NASA centers and very heavily supported by the Office of Aeronautics and Space Technology.

We talked at that time of the need to develop test beds for advanced system development. We ran a competition between the centers as to where those test beds should be located and what plans we should put together for the next several years. We have now come to conclusions on a majority of those, and we will be starting to put those test beds together within the next few weeks. It will take more that a few weeks for them to be finished, but at least we can start on that process now.

With regard to the user interface, the customer orientation of the space station, we have had three working groups working, one on technologies for the space station, one on commercial operation of the space station, and one on science and application. Recently, the Associate Administrator of the Office of Space Science and Application chartered a new advisory committee under the chairmanship of Dr. Peter Banks, who is from Stanford, to examine the potential utility of space station for space science and applications, and we expect a report on that toward the end of this fiscal year. In addition to that, there is an internal planning function operating within the Office of Space Science and Applications on the potential utility of space station to those activities.

We are expecting a complete update of our master data base on utility in space station by March 15, so we are continuing in that iteration, and we will continue to do so during the design effort. We have spent considerable time looking at acquisition options for the design of the space station, how we would go about both managing the activity and procuring the activity. We have a number of options, and we expect to come to some conclusions about the management within the next several weeks.

I mentioned last time that we were going through an iterative process between the needs of the space station, those things that we could do with it, and the potential design of it. I drew a carousel and said we have to go around that carousel several times before we were really satisfied with it. We have completed that third iteration, and it is this design that you see here that came out of that third iteration. But in addition to that, we began to look at a number of other configurations, and we have about six alternatives at the moment which perform the same function and in fact have the same pieces but are put together in different ways. I will talk a little bit about that later. But there are a number of configurations that we have looked at.

Perhaps the most important thing was that we determined, in looking at the potential functions of the space station relative to the configuration, that it was not necessary to select a configuration before we brought the major contractors onboard. That was an important decision point for us because it meant that we could get the contractors on board sooner in a very specific design sense.

I would like to show you one exciting piece of technology that we are using in this process of looking at configurations. Can I have that first vugraph (fig. 1)?

[Figures 1-6 appear at the end of Mr. Hodge's prepared statement, see p. 144.]

This is a photograph of a TV tube. The model that you see on there was generated by a system called computer-aided design system. The operator could put this particular configuration together, which as you can see is very similar to this one. But behind the data bases that produces this are a set of analytical tools which will tell you what the heat on any part is, what the thermal stresses are, what the loads on the system are, how big the thing should be, and starts to do the design process within the computer system itself. This kind of system is used fairly extensively in industry these days; but we are developing this data base as a part of our process to do the system engineering function within NASA. It is an exciting development as far as I am concerned, and we will be showing you more of this as time goes by.

The next slide (fig. 2). The budget, which is why we are here today. The first visible budget we had was in fiscal year 1983 for this planning effort. There was $4 million in the Office of Space Flight, in the advanced development, advanced programs area. The majority of that was used to do a number of in-house studies as we started to put our planning effort together and to pay the final part of the bill toward the requirement studies that we were doing with our eight contractors.

In this year, fiscal year 1984, the budget was split into three pieces: $6 million in the Office of Space Flight; $6 million in the Office of Aeronautics and Space Technology; and $2 million in the Office of Space Science and Applications. We have broken that $14 million down into the areas that I have shown here: $3 million in the utilization area, which is again the continual determination of requirement on the part of users. We have started the technology functions, and I think we will hear some more from Dr. Martin later on about that. There is $2.5 million for focused technology, and $3.5 million for prototype systems. The rest of the money this year is being spent on support studies for our concept development group.

I have worked out an arrangement with each of the other offices to be sure that what they are doing and what we are doing are compatible with each other. In fact, we have a very good set of working agreements between the task force and the various elements of headquarters.

We are asking in fiscal year 1985 for $150 million, which is the first increment of the moneys required to do an extensive definition over a period of about 2 years. It will appear in 3 fiscal years, but the total period of operation for that definition study will be about 24 months. The last few months of that will be oriented toward the selection of the final contractors to bend the hardware.

We will continue with our emphasis on the utilization function, the customer orientation, commercial technology, and science and applications. The largest part of the budget is for advanced technology, and that is taking the technologies which are presently available within the research centers in NASA and making them available to the designers for a determination of the specific technologies that we will need. $58 million is to bring the large contractors on board to start the design process. We expect to bring those in

somewhere in the beginning of fiscal year 1985. Then the smallest amount, $12 million, for some studies which we still have to do in-house and with the support of contractors other than the major design contractors for the beginnings of the development of an information system to help us in our management of the program.

Next chart (fig. 3), please. Utilization. We intend to continue this function throughout the design process. There has been a tendency in the past to develop the needs or the requirements for a program and then go away and design it, and come back to the potential customers when you have finished and say, "Here it is." We believe that we must have a continuous relationship between the customer and the design team, and we will be working on that with the various elements of the customer organizations, and they will in fact be an integral part of the program office. This does seem like a significant amount of money, but we believe it has to be that way. About $10 million of this $14.1 will in fact be managed by the Office of Space Science and Applications and will be oriented towards the science and applications missions.

Next chart (fig. 4). As I said, most of our budget is in the area of advanced technology. There is no doubt that a space station could be built with technologies which are presently available. There is some doubt whether that would necessarily be the cheapest way to do it, either in the short term or in the long term. But when we are talking about systems which are to last 15, 20 or 25 years, we believe it is imperative that we look to those technologies and make sure we select them very carefully.

The Office of Aeronautics and Space Technology has inherent in its budget a base of research of about $30 million. They have been working on this for a number of years. We have taken advantage of that to determine which of those technologies we should now move ahead and start to develop them in a prototype sense to make them available for the space station. We are asking for $34.2 million to focus those technologies, take them from proof of concept to availability for testing in test beds, and $20.2 million for prototype hardware to begin to develop those options that we need in the next 2 years to make our final design decisions. We do have available the shuttle itself to do flight tests. This, again, is a very exciting business because for the first time we can do experiments in space on systems which are not yet mature, because we can bring them back. We believe that this process will allow us to come to conclusions about technology much more rapidly than we could have done in the past.

I would like to give you an example of the sort of technology decisions that we are going to have to make. The one I want to use, although there are many of them, is in the area of solar cells. This particular model is built on the basis of a new technology called gallium arsenide. This little cell here is equivalent in power to the normal cells that we presently have. The reason you can make this much smaller is that, number one, it is much more efficient as a system. But also, it can operate in much higher temperatures. What you do is, you have this little collector here, a concentrator, with the cell down inside. We have to decide whether we are going to go with the conventional technology or the concentrator technology with gallium arsenide. It is a question of whether we can

produce these, whether the increase in efficiency is worth the amount of money we are going to have to pay to develop that further.

That particular model assumes that we have these concentrator arrays on there. If in fact we use this one, it will be about 50 percent bigger. That would make the control problem much more significant. So these things do iterate with each other. If you would like to look at those, I will hand it up to you.

Next slide (fig. 5). System definition area, the next largest amount. We believe now that it is possible for us to bring the large contractors on board at the beginning of calendar year 1985. We have started to put our in-house teams together. We are proposing that the system engineering function be performed in-house in NASA and that the large contractors be used to support that system engineering function and do the detailed design.

We propose to break the functions of the space stations up into a number of packages—three or four—and that will result in six or eight contracts in that timeframe. About a little over $52 million of that $58.3 will be used specifically for those contracts, with the remainder being used, should we need the services of a task-order support contractor at the system engineering level. We believe that will be needed later on. The period of performance of this contract will be 20 months, plus 4 months for the determination of the winners of those designs. Then we will continue with one of those contracts into the development phase. We believe that we can start to bring those on board in fiscal year 1987. So 1987 will be a mixed year between hardware and definition.

Next slide, please (fig. 6). There always has to be a catch-all where you do everything else. There are a number of supporting studies that we need to do during fiscal year 1985, which are in addition to the design. They are particularly related to the whole question of the increase of the productivity of man in space: Suits, robotics, automation, and things of this kind that we want to do independently of a major design contract. This is a very important thing for us to do, to increase the productivity of man in space.

You know, on this mission we are flying the EMU, the extravehicular mobility unit, for the purpose of getting ready for the next mission, where we are going to collect a satellite and repair it in space. We need to go a long way in that direction to improve the efficiency of that system, and perhaps this is where much of this money will be spent in 1985. In addition to that, we will begin to put together the information system by which we will manage the program.

We are proposing an extensive information system, and by that process to very clearly delineate the responsibilities that we need to have between the headquarters group, which will be accountable to Congress essentially and to the Executive for the performance of the program, and the designers, who will be in the various centers of NASA.

Thank you very much.

[The prepared statements, plus answers to questions asked of Mr. Culbertson and Mr. Hodge follow:]

Statement of

Philip E. Culbertson
Associate Deputy Administrator

and

John D. Hodge
Director
Space Station Task Force
National Aeronautics and Space Administration

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Distinguished Members of the Subcommittee:

It is with great pleasure that we present today NASA's initial request for line-item funding for a Space Station program, the next logical major step in this nation's development of space capability. At the outset we would emphasize three major points about the Space Station program:

- Now is the logical time to develop permanent facilities to allow humans to live and work in space;
- The Space Station will build upon the capabilities of the Space Shuttle to enable promising new possibilities in space commerce and exploration and preserve and enhance United States leadership in space; and
- We will initiate the program with an extended two to three-year period to thoroughly define the capabilities, cost and specific components of an initial Space Station.

The Next Frontier

President Reagan's State of the Union call for the development of a permanently manned Space Station is really a challenge to the nation--not only to NASA and the government, but to industry and academia as well. If we are to successfully meet the President's call to inhabit the space frontier "for peaceful, economic, and scientific gain" a national effort

will be required. We believe the country is ready. The President's message builds upon his National Space Policy announced on July 4, 1982, in which basic goals were enunciated for our civilian space program. A permanent Space Station is the logical next step to support and implement these basic goals as we move forward to the space frontier.

An over-arching goal of the President's policy is the preservation of United States world leadership in space. A U.S. Space Station in permanent low Earth orbit with multi-functional capabilities will uniquely demonstrate this nation's technological strength. Another basic goal of the policy is to maximize the economic and scientific benefits of the space environment. A Space Station will capitalize on the capabilities of both advanced automation and permanent human presence to spark the age of space industrialization. Today, promising opportunities lie on the horizon in such areas as pharmaceutical production and the manufacture of high purity alloys and semiconductor materials. The space frontier holds rich promise to enhance the welfare and security of mankind.

Background

Over 30 years ago Wernher von Braun wrote an article for Collier's Magazine entitled "Man Will Conquer Space Soon." The German rocket pioneer described an orbiting "space wheel" 75 meters across housing a crew of 80 people with artificial gravity induced by slow spinning. Von Braun envisioned that this home in space would be erected in sections brought into orbit by cargo-carrying rockets. This solar-powered station would serve as a staging base for manned explorations to the moon and the planets.

While far from the first published Space Station concept, Von Braun's writings in the early 1950's sparked a process of imagination and planning for what then seemed only a fanciful dream--that of the day when humans would live and work in space. After more than three decades of conceptual planning, design, and even short term occupancy in true stations in space, we have arrived at a crossroads--a time when it is logical to commit mankind to that major step--permanent presence in space. It may be useful to briefly retrace some of the earlier steps which have led to this crossroads.

When NASA was created in 1958, a manned Space Station program was a prime candidate for the early exploitation of manned spaceflight. In fact, in 1959 at the first meeting of the Research Steering Committee on Manned Spaceflight, an orbiting Space Station was placed ahead of a lunar landing program. The value of a manned station in such areas as biomedical studies and space operations was set forth in the Committee's deliberations. [Somewhat ironically, the Committee ultimately endorsed a lunar landing goal on the grounds that it represented an end-objective in itself and did not require justification or commitment to larger goals.] President Kennedy's call in 1961 for a lunar landing before the end of the decade relegated the possibility of a Space Station to the post-Apollo era.

Space Station planning and studies, however, did not cease during the phases of the Apollo program. At a Space Station symposium at the Langley

Research Center in 1962 the utility of a Space Station for the assembly and launch of missions from orbit was discussed. In 1963 an office was established at Langley to study the concept of a Space Station to be placed in orbit by the Saturn Apollo launch vehicle. The Manned Orbiting Research Laboratory was to have been a national laboratory in space for biomedical, scientific and engineering experimentation. Interesting, it was designed primarily as a zero-g lab with backup provisions for artificial gravity.

In the mid 1960's the Department of the Air Force was assigned responsibility for the development of what was named the Manned Orbiting Laboratory to establish a manned military presence in space. Tended by the Gemini spacecraft, this cylindrical lab would have been occupied for a period of 30 days after which it would reenter the Earth's atmosphere and be destroyed.

America's first and only Space Station to date, of course, was Skylab which was planned in the late 1960's as a follow-on to the Apollo program. Launched in 1973 and visited for periods of up to 84 days by three crews, Skylab dramatically demonstrated both the value of humans in space and the utility of such a facility for scientific observations and experimentation. This program also laid to rest concerns of man's ability to operate effectively in zero-g for moderate periods.

In the late 1960's planning was also underway for major manned spaceflight programs following the Apollo lunar landing. Both a permanent Space Station and a reusable transportation system were under active consideration. The transportation vehicle would provide access to the station. In 1969 Space Station definition studies were conducted by both Marshall Space Flight Center (MSFC) and the Johnson Space Center (JSC). When the decision was made in 1972 to construct the reusable transportation system first, the Space Station study contractors were redirected to pursue modular Space Station approaches. While Space Station studies remained at a relatively low level during the 1970's as the Shuttle was developed, much useful work was accomplished including the Manned Orbital Systems Concept pursued by MSFC in the mid 1970's, the Space Station Systems Analysis studies conducted in 1976-77 by MSFC and JSC, the Space Operations Center concept studied indepth by JSC in the late 1970's and the space platform studies performed by MSFC during the same period.

In conjunction with the Space Shuttle development, the Spacelab concept was also promulgated and successfully developed by the Europeans. The recent first flight of Spacelab demonstrated once again the value of humans in space as well as the many avenues for scientific research in the space environment.

Mr. Chairman this is only a very brief summary of the many Space Station studies and activities which have occurred over the past several decades but it serves to demonstrate that our current planning is based on a solid foundation of conceptual studies and actual flight experience from which we have learned valuable lessons.

Space Station Concept and Capabilities

The Space Station, as currently conceived, will be a multi-functional facility, placed in orbit and tended by the Space Shuttle. It will consist of both manned and unmanned elements of a modular design to maximize potential for evolutionary growth in both size and technology. It will be designed for indefinite life on orbit through the use of maintainable and "restorable" systems and will incorporate advanced automation technology to maximize productivity.

The current concept for an initial Space Station consists of a habitable base for 6 to 8 people and associated man-tended platforms. Initial operational capability could be realized in the early 1990's. A fully capable Space Station could ultimately perform the following functions:

- o On-orbit Laboratory - for a wide range of science experiments and new technology developments,
- o Manufacturing Facility - to develop and ultimately produce new materials such as high purity pharmaceuticals and semiconductors,
- o Servicing Facility - to maintain and repair or refurbish free-flying satellites and platform payloads,
- o Permanent Observatories - for both manned and unmanned facilities for Earth viewing, planetary and stellar observations,
- o Transportation Staging - for assembling and servicing vehicles destined for higher orbits or lunar and interplanetary travel,
- o Assembly Facility - to construct large structures such as antennas for advanced communications missions, and
- o Storage Depot - for spare parts, consumables, or standby satellites for oncall deployment.

The Space Station would be a multi-functional facility serving a wide variety of needs. It is important to note, however, that new uses not now understood or perhaps even imagined could well be expected as the facility is developed and human creativity is exploited in the space environment.

The preliminary development estimate for achieving this initial Space Station enabling capability in the early 1990's is about $8 billion in 1984 dollars. This preliminary estimate includes definition, design, development and integration of the manned module(s), support modules, experiment platforms, and initial servicing capability and postulates a high degree of commonality among the station elements. The objective of the extensive definition and technology development phase is to validate capability and cost estimates and a modular system design that can evolve and endure.

International Participation

Another basic goal of our National Space Policy is the encouragement of international cooperative activities in the national interest. The President has invited our friends and allies to join the United States in the Space Station program and thus share in the benefits of this endeavor. The Space Station will provide the United States and its friends and allies the opportunity to live and work together in space in the peaceful pursuit of scientific and economic benefits.

As the Subcommittee is well aware, foreign space capabilities are becoming increasingly mature. The Space Station program will provide a unique opportunity for international participation through foreign cooperation in the development of the Space Station as well as through foreign utilization of the capabilities and services it will provide.

International participation will be built upon a long history of successful space cooperation including such recent examples as the Spacelab built for the Space Transportation System by the European Space agency and the Shuttle Orbiter's Remote Manipulator Arm developed by the Canadians. As with the Shuttle, NASA is looking for significant foreign contributions to the Space Station. Cooperation in the Space Station Program will be based on the principles that NASA has been following since its inception: cooperation will be mutually beneficial; cooperative partners will accept full financial and technical responsibility for their own well-defined participation; and the terms of the cooperation will take into consideration what potential partners want in return.

NASA's preliminary planning activities over the past 18 months have taken into consideration the possibility of international participation in the Space Station program. Substantial foreign interest surfaced during this period. Separate, parallel mission requirements studies have been conducted by Canada, ESA, France, Germany, Italy and Japan. These studies were conducted at the initiation and expense of the individual countries. The results of all studies have been shared fully with NASA, and have been extremely helpful to us. The various types of missions identified by the foreign studies have been generally compatible with those identified in the NASA studies.

Several countries have also been looking at what specific contributions they might want to make. It is not surprising that Europe and Canada have been concentrating on building on the capabilities they have already developed for the Space Shuttle. In addition, Italy has begun to study possible applications of the Tethered Satellite System to a Space Station. While Japan did not cooperate in the development of the Shuttle, it has also been taking a serious look at pressurized modules and platforms.

The President has asked Mr. Beggs to visit Europe, Canada, and Japan as his personal emissary to explain the President's Space Station initiative, to assess the extent of foreign interest and to explore opportunities for constructive participation in the Space Station Program.

Now let us briefly review our recent planning activities.

Summary of Task Force Activities

The Space Station Task Force was established by the Administrator in May of 1982 and has been staffed by detailees from all NASA Field Centers and Headquarters program and staff offices. This staffing arrangement has facilitated the program planning objective of agencywide participation. Task Force activities have further been pursued through the use of working groups made up of Task Force members and experts from the appropriate Field Centers.

The first year of Task Force activities was primarily dedicated to the identification of an initial set of Space Station mission requirements. The results of various studies, including those of the eight Space Station mission analysis industry studies, were synthesized at a workshop last May at the Langley Research Center. A total of 107 types of Space Station missions was identified in the areas of science and applications, commercial, and technology development. A computerized data base has been established to continuously trace and update mission requirements.

Last May a Concept Development Group (CDG) was established within the Task Force to focus initial planning for systems engineering and integration. The group has evaluated several iterations of Space Station "architectures" or functional capabilities in order to evaluate various station configuration options to be pursued in the contracted definition phase. With the support of appropriate Field Centers, and at no direct cost to the government, contractors and interested foreign participants, technical studies in areas such as power, thermal control, and autonomy have been performed and the results shared in a series of workshops here in Washington, DC. This past fall a configuration study was initiated primarily to identify trades and issues which must be pursued in the contracted definition phase. A total of six generic types of configurations have been identified and are currently under study.

The Task Force Program Planning Working Group has evaluated management options for the program, planned an information system, and developed an acquisition approach, as described below. Advanced development activities have focused on identifying key technology options, building and integrating prototype components into subsystems for demonstration in ground-based test bed facilities and conducting flight experiments and demonstrations on the Shuttle. Additionally, special attention has been directed to a focused approach to improving human productivity and optimizing the use of automation and robotics in the Space Station environment.

FY 1985 Budget

The following describes the major elements of our request for FY 1985, a total of $150 million, along with some of the major criteria which have guided our planning.

Utilization

From the outset of Task Force planning activities the involvement of the potential user community has been a primary criteria in the definition

of the program. In fact, as we have testified, the first activities of the Task Force were to collect and analyze potential Space Station mission requirements from all potential user communities. This initial effort resulted in the mission synthesis workshop at the Langley Research Center mentioned above at which a total of 107 types of Space Station missions were identified in the categories of science and applications, commercial, and technology development.

A continuous, interactive involvement of the user community will be essential during all phases of the program in order to maximize productivity and responsiveness to Space Station customer needs. To this end our utilization efforts have continued and a strong effort is planned for the coming fiscal year.

In FY 1985, a total of $14.1M is planned for Space Station utilization requirements. The overall objective of the utilization effort is to develop a process which will continually express customer requirements in all aspects of using and operating the Space Station. Utilization planning includes the establishment of a high level mechanism at NASA Headquarters for continuing, credible and effective representation of both internal and external user interests and requirements. Specific FY 1985 activities will include the refinement of requirements documentation with traceability as a prime objective. Formal review processes will be established to control and document requirements evolution.

The primary emphasis which NASA places on user requirements is an acknowledgement that the Space Station as part of the Nation's overall space capability or "infrastructure" is not an end in itself but rather a means to an end which would not exist in the absence of the user community. In a very real sense the users are the "owners and operators" of the Space Station and their needs will dictate the station's operational capabilities. In this regard mechanisms are being established to assure that the requirements process contributes to development of the station performance envelope. This also requires that the utilization function consider commonality, maintainability, and operational practices in the development of this envelope.

Following last year's initial mission synthesis activities the Task Force Mission Requirements Working Group formed Customer Advocacy Panels in the three areas of 1) science and applications, 2) technology, and 3) commercial missions. Additionally, a new science task force headed by Dr. Peter Bunks of Stanford has been formed to advise NASA on our long range science needs and uses of the Space Station. These panels will continue in FY 1985 and serve as the primary focusing mechanism for requirements in their discipline areas.

Utilization functional areas to be pursued in FY 1985 cover a broad range of activities in the areas of customer relations, requirements development, special projects and advanced planning. In addition to the ongoing advocacy panels, customer relations activities will include outreach programs to educate and establish liaison with more of the potential user community--both within the government and without. Advanced

planning will include a focus on the orderly development of space services enabled by the station such as satellite and platform servicing, construction and assembly, and computational services. In the category of special projects attention will be directed to management relationships including development of a master utilization plan and commercial policies.

Advanced Technology Program

NASA's Space Research and Technology program is designed to serve a broad spectrum of advanced space technology needs. The value of this program to the initiation of current Space Station program planning cannot be understated. Focusing of the many generic technologies within this base to a Space Station effort began over two years ago. On the premise that any future Space Station program be based on the most advanced technology available, Administrator Beggs established a Space Station Technology Steering Committee (SSTSC) in the fall of 1981.

In its early deliberations the SSTSC concluded that currently available technology would not meet the needs and goals of a future Space Station program. The steering committee generally concluded that a station based on current technology would not have affordable growth potential and would not be cost effective for indefinite life through on-orbit maintenance. The committee then set about the task of identifying those necessary technologies to meet these primary program goals. The general conclusion was that a concentrated advanced development program would be required to bring these technologies to the necessary state of readiness.

The existence of the generic technology base within the Agency's Space Research and Technology program has provided a rich source of basic technology efforts which can now be focused specifically for Space Station use. Within the FY 1985 total request, $34.2 million is requested for focused technology efforts. This effort is broadly divided into the following six task areas:

The focused technology energy task is directed at advancing energy management technology from the generic research and technology base program through demonstration at the breadboard level. The dynamics and control task is directed toward the development of distributed, modular or adaptive control techniques to be used in place of the rigid body control techniques employed on present spacecraft. The hydrogen/oxygen systems focused technology task will develop the the necessary technologies for the potential utilization of hydrogen and oxygen consumables for the power, propulsion, and crew/life support subsystems. The information and automation task is directed toward providing the technology needed for advanced data system architecture and for human-supervised, computer-managed autonomous control of subsystems, payloads and remote operations. The operations task is necessary to develop computer software for systems simulation of on-board and ground systems design. The enhanced human capabilities task will develop technology to enable human physical and psychological productivity in space.

The Space Station Advanced Development program is designed to bring those high leverage efforts from the Focused Technology tasks to a level of readiness for potential system development. It effectively provides the bridge or transfer function from the technology level to that of prototype hardware development. The successful execution of this effort in the program definition phase demands adequate resources if the capabilities inherent in the promising technology tasks are to be realized.

The primary mechanism for evaluating technology alternatives will be a series of test beds in a number of major discipline areas. These test beds will be located at agency centers of expertise and will be available for in-house evaluation and testing and similar use by the definition contractors. Incentives and resources will be included in the definition phase contracts to encourage maximum utilization of the test beds and coordination with NASA in-house efforts.

The development of automation technologies will be emphasized in each of the test bed areas. Within the overall plans for Space Station automation, test bed objectives will stress the application of automation in areas such as fault detection and isolation, servicing and repair, and routine operations functions. A total of $20.2 million is requested for advanced development and test bed activities in FY 1985.

One of the capabilities which will ultimately be afforded by the Space Station will be the ability to test and checkout new equipment and procedures in the space environment with essentially no constraints on time on-orbit. It is expected that this capability will lead to the elimination of many expensive ground-based simulations and tests which are now considered necessary prior to actual spaceflight. In the interim, the Space Shuttle will be utilized to space test a number of critical Space Station technologies and procedures. In FY 1985 a total of $11.0 million is requested to initiate Space Shuttle flight experiments to validate the performance of Space Station components and subsystems.

Shuttle flight testing will be employed in key areas to verify and quantify calculated performance, to identify unforeseen anomalies, and to update engineering design criteria flowing from the Advanced Development Program and definition efforts. Current candidate flight experiments include environmental control and life support system hardware, cryogenic fluid management, thermal systems, and contamination and plasma effects.

This effort will be closely coordinated with the on-going Space Shuttle experiments directed for the agency by the Office of Space Flight. In this regard the upcoming mission to retrieve and repair the damaged Solar Maximum Mission spacecraft represents the true initiation of space satellite servicing. The lessons learned from this unique mission will be an invaluable first step on the road to routine space-based repair and maintenance.

System Definition and Integration

As the Administrator has testified, a primary criterion which has guided our planning efforts is the necessity for an extended program definition phase prior to initiating development and hardware production. In the coming fiscal year $58.3 million is requested to initiate a two year contracted definition effort.

The system definition program phase provides for the analysis of data generated during the conceptual phase of the program and the development of the overall configuration and preliminary design to define the various elements which will be produced in the development phase. Space Station planning criteria have focused on the desirability of both wide contractor and agency participation in the program.

The current approach to program definition is to divide the effort into major work packages with different functional capabilities assigned to each work package. Requests for proposals for the various work packages would be released sometime this summer with contract initiation in FY 1985.

Systems integration and engineering of the program elements and subsystems during the definition phase would be performed by a dedicated organization at a lead Field Center with appropriate industry support. The various work packages would be managed by Field Centers with appropriate expertise and overall coordination and integration would be the responsibility of the lead Center.

This approach to program definition maximizes both industry and NASA Field Center participation in the program and will serve to enhance in-house capabilities in the areas of program management, procurement, and systems engineering and integration. It will also provide a focus and mechanisms for integrating the results of the Advanced Development program into the definition effort.

Supporting Studies and Program Support

Over the past 18 months several hundred in-house trade studies have been initiated to lay the groundwork for the many decisions necessary in areas such as station structures and mechanisms, auxiliary propulsion techniques, and maintainability of on-board systems. In FY 1985 a total of $12.2 million is requested to further these studies and provide necessary program support.

A primary element supported by this funding is the development of a Space Station information system. The ability to track program milestones and resources in a timely fashion is critical to effective program management. The information system planned for this program is a distributed system operating on a master data base designed to serve both technical and administrative needs. Properly implemented, the system will enhance productivity through individual work stations linked for rapid access to centralized data bases. The system will reduce paperwork and allow top management to make timely, informed decisions through improved communications and analytical capabilities.

Other supporting studies will be directed toward both the Space Station operational environment and advanced planning to assure the potential for future Space Station capabilities.

Conclusion

A Space Station program is the logical next major step in this Nation's development of capability to exploit the many potential economic and scientific benefits of the space frontier. With the reality of an operational Space Shuttle, the time is ripe to initiate this program. NASA's FY 1985 request will allow for indepth definition and advanced technology development of a Space Station program that will maintain United States leadership in space and open many new possibilities for commercial and scientific returns.

SPACE STATION
FY 1985 BUDGET
(Real Year $ In Millions)

	FY 1983	FY 1984	FY 1985
UTILIZATION	1.3	2.9	14.1
ADVANCED TECHNOLOGY	.6	6.0	65.4
SYSTEMS DEFINITION/ INTEGRATION	--	--	58.3
STUDIES AND SUPPORT	2.1	5.1	12.2
TOTAL	4.0*	14.0*	150.0

* FUNDED AS PART OF OTHER PROGRAMS' BUDGETS.

FIGURE 1

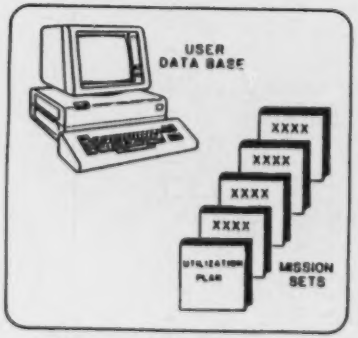
UTILIZATION $14.1M

OBJECTIVE: THE CONTINUAL INVOLVEMENT OF USERS IN ALL ASPECTS OF DEVELOPING AND UTILIZING A SPACE STATION.

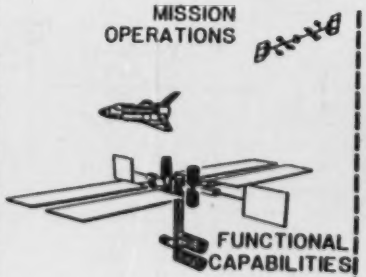
APPROACH: OUTREACH TO USER COMMUNITY

ADVOCACY GROUPS → { SCIENCE & APPLICATIONS, TECHNOLOGY DEVELOPMENT, COMMERCIAL } → CUSTOMER NEEDS → SPACE STATION DESIGN & OPERATIONS

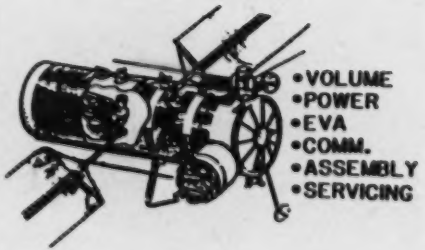
FY 1985 PRODUCTS:



CUSTOMER NEEDS



TOP LEVEL PROGRAM REQUIREMENTS



PERFORMANCE ENVELOPE

Figure 2

ADVANCED TECHNOLOGY PROGRAM
$65.4M

OBJECTIVE: PROVIDE ADVANCED TECHNOLOGY OPTIONS TO ENHANCE THE INITIAL AND LONG-TERM PRODUCTIVITY OF THE SPACE STATION

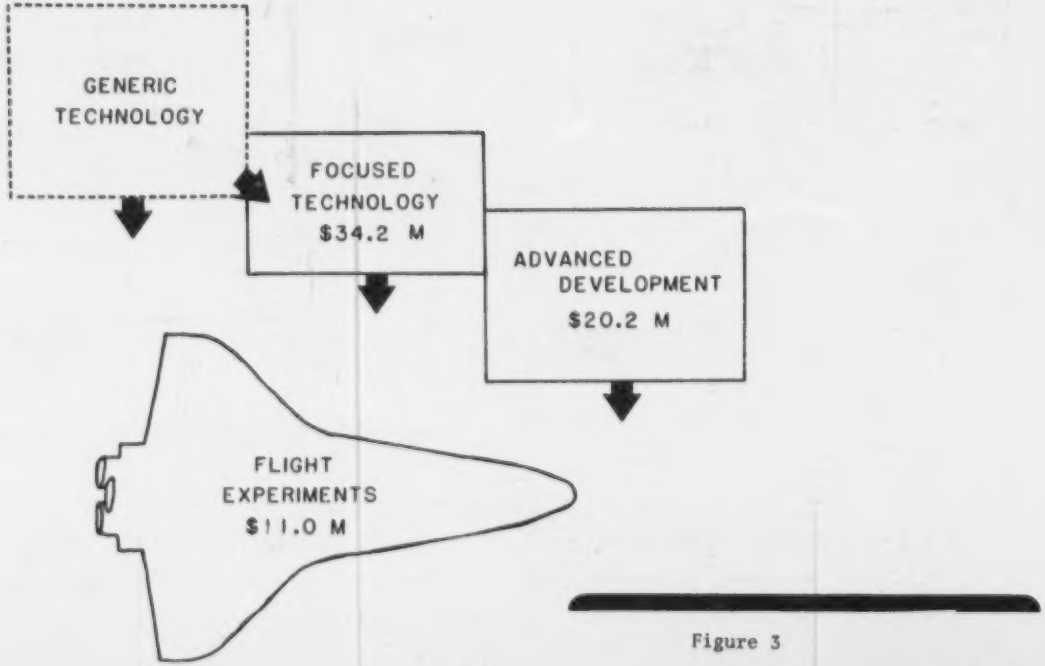


Figure 3

SYSTEMS DEFINITION

$58.3M

OBJECTIVE: CONDUCT IN-DEPTH, EXTENDED PHASE OF ANALYSIS AND PRELIMINARY DESIGN TO THOROUGHLY DEFINE SPACE STATION PROGRAM ELEMENTS

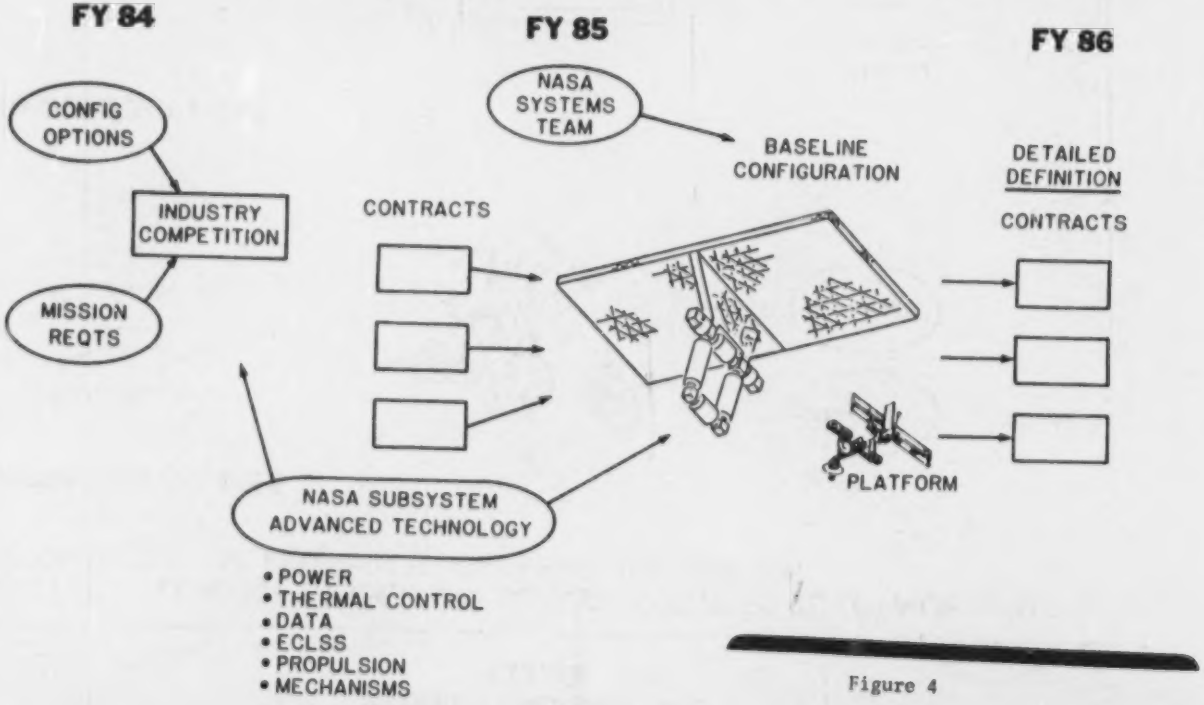
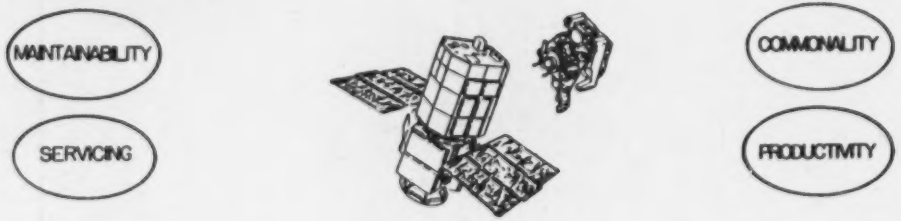


Figure 4

STUDIES AND SUPPORT
$12.2M

OBJECTIVE: CONDUCT STUDIES AND SUPPORT ACTIVITIES TO OPTIMIZE SPACE STATION DESIGN AND PROGRAM MANAGEMENT AND CONTROL

SUPPORTING STUDIES



PROGRAM SUPPORT

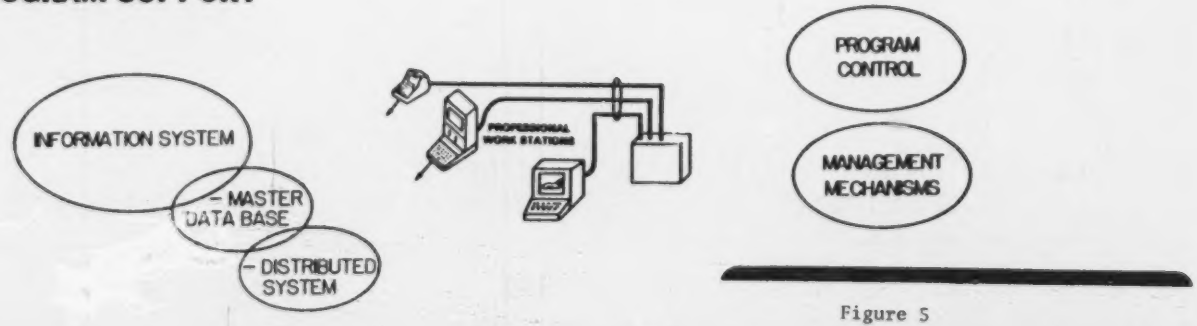


Figure 5

RESPONSES TO WRITTEN QUESTIONS SUBMITTED BY CONGRESSMAN VOLKMER DURING THE HEARING BEFORE THE HOUSE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS ON FEBRUARY 2, 1984, TO MR. CULBERTSON AND MR. HODGE.

QUESTION MFA-1:

Recent experience with NASA has demonstrated the potential for space transportation systems development and operation to seriously impact funding for other NASA programs.

a. How will you ensure that the Space Station will not encroach on other programs?

b. How would you characterize the level of technical risk associated with the space station?

c. How have you formulated project reserves to accommodate schedule slippage and technical difficulties that arise?

d. What technologies remain to be developed?

e. What amounts of funding are planned in the science and applications program to exploit the Space Station?

ANSWER MFA-1:

a. The President's five year projections include real growth in NASA activity of 1 percent a year over the FY 1986-1989 period. This budget projection does allow for new initiatives in addition to the Space Station. That fact along with our extended definition activities planned for the FY 1985-1987 period will enable us to embark on a phased development buildup with a sound understanding of the job to be done within stated agency budget guidelines.

b. There are no "high risk" technologies under consideration for the Space Station. The station will be based on advanced state-of-the-art technology of the 1990's. (See answer to Question MFA-10).

c. The current estimates do contain a reserve to apply against future technical problems.

d. The level of technology required for the Space Station is understood and is proceeding toward maturity in the 1990's. (See Question MFA-10 for a listing of candidate technologies for further development).

e. Science and Applications funding is projected to increase substantially within the next five years and a significant portion of these funds will be available to exploit Space Station capabilities.

QUESTION MFA-2:

How will transport operation for resupply and logistics impact the goals of cost recovery for the Shuttle? Will Shuttle flights in support of station construction and development be charged to the station?

ANSWER MFA-2:

It is our intent to have as much commercial and international participation on the Space Station as feasible. To the extent that the Shuttle operational flights are carrying payloads in support of commercial Space Station operations, these costs would be reimbursable. The Shuttle flights in support of the initial establishment of the Space Station in orbit are not included in the $8.0 billion development estimate.

QUESTION MFA-3:

NASA has articulated the view that the Space Station development will be an international cooperative development.

a. In the context of the current international competition, what will other countries have to gain by such participation?

b. How will operation and services allotted to other users be related to their commitments during the developmental phase?

c. Will independent operations by other users be considered?

d. What policy guidelines have been established for international participation?

ANSWER MFA-3:

In his State of the Union message, the President announced that he wanted our friends around the world to help us meet the challenge of space and share with us in its benefits.

International cooperation in space activities allows the United States and other countries to undertake more expansive activities in space than would otherwise be possible. International involvement in the Space Transportation System's development has led to procurement by the United States of follow-on production articles, flights of international payload specialists, and numerous payload opportunities.

NASA has followed a consistent set of guidelines for international participation in its activities. Cooperation must be mutually beneficial and take the form of discrete hardware pieces. Partners assume full financial and technological responsibility for their clearly defined portion of the program. The application of these guidelines to the Space Station will be reviewed over the next few months.

The President has asked the NASA Administrator to visit Europe, Japan and Canada to discuss the Space Station initiative, assess foreign interest, and explore opportunities for cooperation. Upon his return, Mr. Beggs will join Secretary of State Schultz to report the findings of this trip to the President.

QUESTIONS MFA-4:

Has NASA been able to articulate a cost/benefit justification for the space station?

ANSWER MFA-4:

NASA has not formulated a detailed cost/benefit analysis for the Space Station. High-leverage programs such as this have traditionally contributed significantly to the Nation's economy as well as providing important new technologies.

QUESTION MFA-5:

What, if any, adverse effects would a delay in the Space Station startup have?

ANSWER MFA-5:

A delay in initiating the Space Station would send the wrong signal to those foreign countries which appear interested in participating in the U.S. Space Station program. The signal would be one of hesitation and lack of purpose on the part of the United States. A similar signal would be sent to American industry and to the American people. Delay, moreover, would stretch out the station's development schedule beyond the most efficient timetable thereby adding unnecessary cost to the program and pushing further into the future the date of the station's Initial Operating Capability (IOC).

QUESTION MFA-6:

We understand that some past senior NASA officials and at least one major aerospace contractor have expressed the view that the initial size and capability of the Space Station should be cut back from the currently favored NASA designs. Given that the Space Station is going to be modular in design and can readily be expanded in size, why does it not make sense to start out a little smaller (with a crew size of 3-4, for example) and then add to the facility as mission requirements evolve?

ANSWER MFA-6:

While there were some differences of opinion among the NASA mission analysis contractors prior to the synthesis workshop held in May at the Langley Research Center, all contractors now agree with NASA's projected requirements and capabilities for the station. While the missions that have been identified are not necessarily the actual missions that will fly in the 1990's, they are a representative set that has been used to define the capability that a facility such as the Space Station should have. Utilization requirements will

continue to be examined throughout the definition period and new requirements, as identified, will be factored into the definition process.

QUESTION MFA-7:

In the past, NASA had set 1991 as the year in which it wanted to have the Space Station in orbit. We have been led to believe that to meet this date, NASA would have to follow a funding profile that is essentially the same as those followed by "crash programs" (with funding ramping straight up and then ramping straight down). Given the 10-year time frame set by the President for developing the Space Station, and the lack of a compelling reason to race to develop it sooner, wouldn't a more traditional funding profile and development pace seem prudent?

ANSWER MFA-7:

The funding profile proposed for the Space Station does not reflect a "crash program." The extended definition NASA intends to follow allows for a buildup in FY 1987 that is consistent with an initial capability in the early 1990's. The peak funding would be about $1.6 billion a year (FY 1984 $) for several years rather than a steep ramp up and corresponding rapid decrease. Our approach will enable the Agency to incorporate both the Space Station development and other new starts within the projected 1 percent per year growth stated by the President.

QUESTIONS MFA-8:

a. Could you describe the management approach planned for the space station?

b. Some have suggested that the "lead center" management approach on the Space Shuttle program contributed to the management and cost and schedule problems. What are the lessons that were learned?

ANSWER MFA-8:

a. The lead center management approach will be used for management of the Space Station.

b. The lead center management approach has been used successfully on numerous NASA programs in the past. The recent study of NASA project management requested by the Committee on Science and Technology identified several useful policy changes. One significant change is extensive definition of projects before detailed cost and schedule commitment. This approach is planned for the Space Station program.

QUESTION MFA-9:

What will be learned from just building the Space Station?

ANSWER MFA-9:

Building the Space Station has two aspects: development of the station's elements and systems and the assembly of the station itself in orbit. We will learn from both. From the latter, we will add significantly to our understanding of assembling structures in space, particularly in regard to Extravehicular Activity (EVA). From the former, we will learn about automation, and robotics for the station's design will emphasize advanced systems in these fields. We will also make significant advances in the areas of data management, environmental control systems, power and the like.

QUESTIONS MFA-10:

What are the high risk technologies associated with the Space Station?

ANSWER MFA-10:

There are no "high risk" technologies under consideration for the Space Station. The objective of the Space Station Advanced Development program is to develop and demonstrate new high leverage technologies to a schedule that will take the "risk" out of the hardware development phase. Over forty percent of the planned FY 1985 budget is for developing the technologies we believe are necessary to provide us with a Space Station with improved efficiency and effectiveness. Work has been planned to focus these technologies to a Space Station application, building, and integrating prototype components into subsystems for demonstration of promising technology options in ground-based test bed facilities, and conducting flight experiments utilizing the Space Shuttle. A list of the candidate technologies for further development follows:

By Technology Discipline

- Power:
  - High Capacity Energy Storage
  - Improved Performance Solar Arrays
  - Fuel Cell Electrolysis
  - Automated Power Subsystems
  - High Voltage/Power Components
  - Bulk Power Transfer
- Environmental Control and Life Support:
  - Extravehicular Activity - Suit
    Mobility Aids
    Tools
  - Crew and Work Station Accommodations
  - Regenerable Life Support System
- Auxiliary Propulsion:
  - Low Thrust Gaseous Hydrogen/Oxygen Auxiliary Propulsion System Components
  - Cryogenic Fluid Resupply
  - Cryogenic Fluid Management
  - Electrothermal Thruster System

- o Data Management:
  - High Speed/Capacity Data Systems
  - Fault Tolerant Systems
  - Bubble Memory Systems
  - Adaptive Data Networking
  - Software Management

- o Structures/Mechanisms:
  - Advanced Materials for Active/Passive Damping, Coatings, and Films
  - Rendezvous, Docking, Berthing Systems
  - Advanced Mechanisms
  - Structural Concepts, Dynamics and Analysis for Large Arrays, Solar Arrays

- o Thermal:
  - Integrated Thermal Utility/Thermal Bus
  - Maintainable/Replaceable Radiator
  - Long Life Heat Rejection
  - Versatile Thermal Acquisition and Transport

- o Human Capabilities:
  - Habitability Requirements for Extravehicular and Intravehicular Activity (EVA and IVA)
  - Man/Machine Function Allocations
  - Human Interface to Intelligent Systems
  - Direct, Supervisory and Automatic Control of Teleoperators and Robotics
  - Orbital Maintenance Methodology
  - Medical Aspects

- o Attitude Control and Stabilization:
  - Predictive Methods for Large Spacecraft Response
  - Integrated Analysis Methods
  - Advanced Guidance and Control Components
  - Large Momentum Management Devices

- o Communications:
  - Multiple Use Antennas
  - Infrared Communication Systems
  - Accurate Ranging and Tracking Systems
  - 60 Gigahertz Devices/Components
  - Vehicle-to-Vehicle and Vehicle-to-Station Communication Systems

- o Systems/Operations:
  - Autonomous Systems
  - Hierarchical Control
  - Self Diagnosis/Repair
  - Integrated Crew and Life Support/Energy Management System Development
  - Attitude Control/Energy/Crew and Life Support System Development

QUESTION MFA-11:

Have you considered the vulnerability of the Space Station under various hostile environments?

ANSWER MFA-11:

Yes, as characterized by the natural space environment (radiation and meteoroid particles), the induced space environment (effects induced by a spacecraft in the natural environment), and space debris. Current investigative efforts and data generated by past space missions will be used to update our knowledge of the natural and induced space environment. This characterization will be factored into the design and operation of the Space Station to minimize its on-orbit vulnerability. Specifically, the internal design will have built-in safety margins and a "safe haven" will be provided in every habitable module.

QUESTION MFA-12:

Will the Space Station that you are proposing be more capable or less capable than the current Soviet Union capability?

ANSWER MFA-12:

The NASA Space Station concept includes far more capability than the current Salyut. The concept includes a much higher power level, more laboratory space, commercial involvement, more satellite servicing capability, more provisions for attached payloads (e.g. telescopes), much more provision for research and development activities, much more total volume, greater data transmission capability, and more productivity through an optimum mix of both human and automated capabilities.

QUESTION MFA-13:

What are NASA plans to make Space Station available for commercial users?

a. Several private companies have entered the commercial space business in the areas of launch vehicles and unmanned platforms. At least one company is interested in building an intermittently manned space platform for commercial lease. Will the NASA Space Station compete with private industry? Has NASA developed any ideas on a charge policy for commercial users?

b. NASA has recently signed an agreement with Fairchild giving them them exclusive rights to unmanned platforms below the 12.5 kw range. Yet the current NASA Space Station planning includes multiple NASA-provided platforms. Does this represent a conflict?

ANSWER MFA-13:

a. It is NASA policy to not compete with private industry. On the contrary, where private industry exhibits an interest in providing a space service, NASA will foster and encourage the involvement of the private sector. (See answer to Question 36). This policy will be followed in the provision of Space Station capabilities. NASA has not yet developed a pricing policy for commercial Space Station users.

b. NASA does not believe this represents a conflict. While the current Space Station concept includes platform capability for government science and application missions, the Agency will not compete with commercial providers of platform services for private sector users.

QUESTION MFA-14:

In what ways and to what degree is the Space Station program expected to affect the U.S. economy?

ANSWER MFA-14:

The Space Station is expected to affect the U.S. economy in several ways. First, the program will encourage the participation of industry in many areas, some currently identified and many more yet to be discovered. Promising commercial potential has been identified in materials processing disciplines such as pharmaceuticals and crystal growth. Second, the R&D investment will stimulate the economy as previous NASA programs have. Finally, a continuing presence in space will enable the country to proceed with other endeavors, both scientific and commercial, which will stimulate the economy on their own.

QUESTION MFA-15:

What degree of international involvement do you see in Space Station, and what are the policies governing the technology transfer between countries?

ANSWER MFA-15:

Based on the interest shown to date, NASA expects significant international involvement in the Space Station program, in both the development and utilization phases. The major space partners of the United States (Europe, Canada and Japan) have spent more than $6 million of their own funds over the past two years to study potential uses of the Space Station and potential hardware contributions. Foreign industry, like U.S. industry, has also invested its own funds in these studies. Furthermore, the response to the President's State of the Union message has been overwhelmingly positive.

NASA has always conducted its international activities so as to minimize unwarranted technology transfer, and will do so in the Space Station program, as well. In cooperative activities, NASA looks for discrete hardware contributions. Furthermore, foreign partners are expected to assume full financial and technological responsibility for their portion of the program. NASA provides only that information which is necessary to achieve effective interface between the NASA and foreign contributions.

QUESTION MFA-16:

To place a Space Station in orbit, what kind of impacts will be imposed on the current Space Transportation System?

ANSWER MFA-16:

As currently conceptualized, one dedicated STS flight will be required in the beginning to provide for assembly and checkout of the station. Additional flights to assemble the remainder of the Space Station need not be dedicated but can be co-manifested with other planned flights. The resupply, nominally on 90-day intervals, can be co-manifested with other flights to the same vicinity. Since the Space Station will be in a 28.5 degree orbit, many flights will be scheduled to that proximity and co-manifesting will be facilitated. Overall, impact to the Space Transportation System will be minimal.

QUESTIONS MFA-17:

How will Space Station impact NASA's ability to support:

a. The Shuttle

b. Scientific use of the Shuttle

c. Commercial use of the Shuttle for research (i.e., space manufacturing)

ANSWER MFA-17:

a. Once the Space Station has been established in orbit, it could require about 3-4 flights per year for recurring logistics missions. The Shuttle flight model is expected to be on the order of 24 flights a year in that time frame so the impact on the Shuttle should not be significant. Also, the possibility for co-manifesting other payloads on Space Station missions will allow maximum use of Shuttle capabilities.

b. An operational Space Station would allow the Shuttle to be used as: an efficient transportation mode to and from low-Earth orbit. Scientific missions, other than short duration ones that could be performed on the Shuttle, would be done on the Space Station, taking advantage of the stations repair and assembly capabilities as well as its permanence in orbit.

c. Commercial applications should have a better return on investment in the Space Station environment rather than on the Shuttle.

QUESTION MFA-18:

What information is currently available to indicate that the benefits of a Space Station will exceed the benefits of alternative methods of accomplishing NASA's goals for the Space Station?

ANSWER MFA-18:

Such information is available in the "mission analysis" studies of Space Station requirements and architecture carried out independently last year by eight aerospace companies. Their analyses pointed to potential benefits obtained through Space Station

capabilities. For example, in the area of commercialization, the studies showed that a manned Space Station would enable the rapid development of new pharmaceuticals in contrast to other systems such as the Shuttle which is constrained in its time on orbit. The mission analysis studies also pointed to the effectiveness of a space-based orbital transfer vehicle in delivering communications satellites to geosynchronous orbit. In addition, future goals in space may well include a return to the moon or expeditions to Mars or other parts of our solar system. A Space Station incorporating the function of a transportation node could enable such goals to be realized. Moreover, benefits of a Space Station to the disciplines grouped together as Life Sciences are considerable particularly in contrast to alternative capabilities.

QUESTION MFA-19:

Has NASA assessed the benefits of developing high technology subsystems for Space Station that will later reduce the cost of future manned space flight?

ANSWER MFA-19:

Inasmuch as the Space Station is a manned system, all the technology that will be developed for its design and operation will have the potential of reducing the cost of future manned space flight. Since the Space Station is to be a permanent facility in space, NASA is carefully assessing the cost avoidance potential of all new technology. For instance, the synergistic use of hydrogen and oxygen in the life support system, power system, and the propulsion system are being evaluated. Automation technology will be systematically applied across all major subsystems to enable efficient in-space operations. A regenerable life support system technology is being pursued which will reduce the need for costly consumable replenishment of oxygen and water. This technology will provide a cost-effective capability for future manned space flight missions. In addition, the Space Station will utilize technology that will permit efficient and graceful evolution in terms of increased performance and capability.

QUESTION MFA-20:

Is the Space Station a necessary precursor to more ambitious long-term initiatives, such as lunar or planetary exploration? Will the Space Station have adequate capability to support such initiatives?

ANSWER MFA-20:

NASA currently believes that a Space Station incorporating the function of a transportation node or staging base is essential for future endeavors beyond the Earth, such as a lunar base or a Mars Sample Return Mission. The proposed Space Station will not be able to support such endeavors though it will be designed from the beginning to be upgraded for such missions should the Administration and Congress so decide.

QUESTION MFA-21:

Is a Space Station the "next logical step" in our civil space program? What other "next steps" have been considered, and why were they rejected?

ANSWER MFA-21:

NASA believes the Space Station to be the next logical step in space. The operational maturity of the Space Shuttle provides dependable and efficient access to and from low-Earth orbit. A multi-purpose Space Station will take advantage of this unique transportation capability and, in combination with our experience and plans for space science and applications, will provide a permanent and unusually capable presence in space for the United States. Among the alternative steps that could have been pursued were the establishment of a lunar base or an expedition to Mars. Beyond reasons of cost and timing, these possibilities were considered premature as the Space Station itself is an enabling capability for such undertakings.

QUESTION MFA-22:

What are the limitations to achieving a permanent human presence in space by telepresence -- that is, by keeping the physical human on the ground and only placing his sensors and effectors in orbit?

ANSWER MFA-22:

The use of teleoperation is practically limited by the transmission time delay between the remote system and the human operator. For systems in low-Earth orbit, this amounts to only several milliseconds and is substantially smaller than the response latency of human reflexes. However, a more basic constraint involves the present state of sophistication in teleoperation. Current teleoperation does not equal the overall envelope of human capabilities although for small subsets of related tasks, teleoperation is superior to human performance. The question implies that teleoperation is an alternative to a manned presence. Within NASA, teleoperation and a manned presence are viewed as complementary. Man's intellectual and physical skills will be employed in a pathfinding fashion to accelerate the development of teleoperation in space operations. As teleoperation improves, it will provide an adjunct capability to human extravehicular activity.

QUESTION MFA-23:

What are the advantages of a Space Station? Can't we do most Space Station functions by unmanned missions?

ANSWER MFA-23:

The Space Station will provide the coupling of a long duration, highly automated facility in space with the unique capabilities of man for cognitive, innovative interaction. The station will be a multi-functional facility with a wide range of capabilities. These capabilities will enable the Space Station to perform a variety of functions:

- o on-orbit laboratory - for a wide range of science experiments and new technology developments,

- o manufacturing facility - to develop and ultimately produce new materials such as high purity pharmaceuticals and semiconductors,

- o servicing facility - to maintain and repair or refurbish free-flying satellites and platform payloads,

- o permanent observatories - for both manned and unmanned facilities for Earth viewing, planetary and stellar observations,

- o assembly facility - to construct large structures such as antennas for advanced communications missions; and,

- o storage depot - for spare parts, consumables, or standby satellites for oncall deployment.

The provision of these capabilities is highly dependent on the presence of crew members both to supervise the operation of autonomous systems and to apply other intellectual, sensory, and motor skills. Unmanned systems can generally be employed to perform routine tasks or operations which have expected results. Human capabilities are necessary where results cannot be predicted in advance and where real-time judgments must be applied as in scientific experimentation and proto-type manufacturing operations.

QUESTION MFA-24:

Can we stay abreast of technology without a major space goal such as Space Station?

a. Would major competitors such as USSR, Japan, ESA/European go for Space Station if the United States does not?

ANSWER MFA-24:

Technology progress often results from the need to develop solutions to stated problems. The Space Station will support advances in the technological state-of-the-art. Whether it would advance as fast without a major goal is unknown. We believe the initiative to develop and validate new technology for the Space Station will have the effect of invigorating American industry to advance the state-of-the-art across a broad technological front for two key reasons. First, it is estimated that over 75 percent of the investment that NASA will make in technology for the Space Station will be distributed to industry. Second, the up-front recognition that technology will provide a discriminator in the ability of companies to compete for Space Station definition and development contracts should stimulate industry to advance this Nation's leadership in new and innovative space technology.

a. The Soviets have pursued a manned space station program since at least 1971 when the first Salyut class space station was launched. The USSR has flown a total of six operational Salyut

space stations and appears committed to the establishment of a permanent human presence in space.

While Europe has indicated a strong interest in cooperating with the United States in a Space Station program, it has also exhibited strong signals that it would pursue development of a Space Station on its own if the opportunity in the United States did not materialize. Europe has studied its own Space Station concepts, both manned and unmanned. Furthermore, we have seen increasing signs of a closer relationship between Europe and Japan, so there is potential for cooperation between them in this area.

QUESTION MFA-25:

What are the more important specific national civil space goals that would require the use of a Space Station infrastructure for their attainment? What are alternative ways to reach those goals?

ANSWER MFA-25:

NASA's civil space activities are formulated within the context of the National Aeronautics and Space Administration Act of 1958, as amended, which calls for U.S. leadership in space activities. The President's National Space Policy of July, 1982, includes the basic civil space goals of maintaining U.S. space leadership, obtaining economic and scientific benefits through the exploitation of space, expanding U.S. private sector investment and involvement in civil space activities, and promoting international cooperative activities in the national interest. The President's direction to NASA to develop a permanently manned Space Station will serve to both reinforce and implement these goals in the decade of the 1990's. While one alternative approach to achieving these goals could be the continued utilization of the current infrastructure, that is, the Space Transportation System operating in conjunction with free-flying satellites and platforms, it is improbable that this approach would result in full realization of these goals in the decade of the 1990's.

QUESTION MFA-26:

What are the various functions and services desired by the public and private sectors of any permanent space infrastructure? Who have requested that they be provided?

ANSWER MFA-26:

The various functions desired by the public and private sector include laboratory research and development, communications and data processing, and storage and servicing. Servicing would include assembly, checkout, and reconfiguration for transportation to higher energy orbits. These functional needs have been developed from requirements gathered by the Space Station Task Force over the past two years from many sources including U.S. and international commercial, technology and science communities. The Space Science and Space Applications Boards of the National Academy of Sciences have stated that the above functions would represent significant

increases in capability contributing to future science and technology developments. In addition, more than fifty specific commercial firms have been identified with interests in potential space-based operations. These firms are for the most part industrial concerns with no prior aerospace experience.

QUESTION MFA-27:

Who would be expected to provide the various elements of the infrastructure? Who would pay for them? Use them? Own and operate them?

ANSWER MFA-27:

Current planning calls for NASA to provide the proposed Space Station capability. Consideration is being given to both private sector and international involvement. This participation could take the form of capabilities which will add to and enhance those of the proposed station. Use and operation of the Space Station will be on a cooperative basis; groundrules have not yet been determined.

QUESTION MFA-28:

What steps have been and will be taken to see that, in general, the cost of achieving space goals, whether achieved with use of a "space station" (manned or not) or by other means, will be the lowest reasonably possible and that, in particular, it will be the lowest reasonably possible to the United States, to the American taxpayer, and to the American civil space program?

ANSWER MFA-28:

It is our firm conviction that an extended definition program combined with a relatively stable budget environment will enable us to develop a Space Station with the best return on the Nation's investment.

QUESTION MFA-29:

What alternative kinds of infrastructure have been studied and discarded, and why? What alternatives remain?

For example, suppose that (a) the orbiters of the Shuttle fleet were modified so as to be able to remain in orbit for up to a month at a time, and (b) this fleet were augmented by appropriate free-flying platforms; if so, what desired capabilities would still remain unprovided that seemingly call for an all-new, permanent, Space Station?

ANSWER MFA-29:

The alternate infrastructures that have been studied include: continuing with only the present Space Transportation System; the present Space Transportation System augmented with additional resources to increase on-orbit capability; the augmented Space Transportation System plus two unmanned platforms; a Space Station designed only as a transportation node; a Space Station designed

only as a transportation node but augmented with two unmanned platforms; a Space Station of greater scope and magnitude than the proposed Space Station; a Space Station with no platforms; a Space Station with only one platform; a Space Station with no Orbital Transfer Vehicle capability; and an infrastructure that includes the present Space Station capability plus another manned base at polar orbit.

Several different levels of augmentation of power and crew facilities have been studied. Scenarios including augmented orbiters without unmanned platforms and scenarios with augmented orbiters plus platforms have been studied. None of these scenarios has shown the augmented orbiter systems to be the full equivalent of the continuously manned Space Station or to be a good substitute for it. The Space Station uniquely provides the capability of continuous manned presence for cognitive, innovative interaction plus adequate power and microgravity levels for materials processing, readily available on-orbit servicing capability, adequate laboratory volume for research, and the time and space for the construction of very large space structures.

QUESTION MFA-30:

Is there any urgency in the procurement of any portions of the infrastructure?

ANSWER MFA-30:

NASA plans the procurement of the manned, unmanned, and transportation elements of the Space Station as an integrated program so as to assure maximum use of common equipment. This approach permits both replication and distribution of functions in the various related program elements. It also eliminates unnecessary overlapping of development efforts.

QUESTION MFA-31:

Are there any important program thresholds; i.e., are there any minimum operational capabilities (i.e., an in-orbit electrical power level) in the sense that to provide less would not be sensible?

ANSWER MFA-31:

With the currently identified range of missions, materials processing pilot production, research and development, plus science and applications missions, the currently identified initial operational capability levels, such as the power requirement of 75 kilowatts, appear to be the minimum necessary to meet projected needs. A reduction of on-orbit time, crew, power and other resources would severely limit the Space Station's capability to support the type of missions that it enables, i.e., to support missions that are beyond the capability of the Space Transportation System.

QUESTION MFA-32:

Given the magnitude and rate indicated for any such Federal expenditures, and the Shuttle program's large and continuing demand for funds, what are the impacts of the total of such expenditures (for Shuttle plus Space Station) expected to be on other Federal civil space RDT&E areas such as space science, space applications, and space technology development?

ANSWER MFA-32:

As stated by the NASA Administrator, the Space Station can be developed by the early 1990's within the current projection for the NASA budget without impacting other areas of the civil space program. NASA intends to have a strong Space Science and Applications program during the development and operation of the Space Station.

QUESTION MFA-33:

Have other Federal departments and agencies been included in the identification of desired infrastructure characteristics, and what are their specific intentions regarding supporting its procurement, maintenance, and use?

ANSWER MFA-33:

The Department of Defense participated in mission analysis activities and is represented on the Space Station Task Force. Briefings have been given to the intelligence community. No requirements have as yet been identified by these agencies.

QUESTION MFA-34:

What steps are planned to include the private sector investment and involvement (both potential providers and users), directly, in the selection of the space infrastructure characteristics and capabilities, and in the plans for its provision, use, and financing? Similarly, for other countries and country-groupings?

ANSWER MFA-34:

A basic goal of our National Space Policy is to expand private sector involvement in civil space activities. A commercialization office at NASA Headquarters will be established to serve as a focal point for our activities in this regard. Within the Space Station Task Force a commercial advocacy group has been formed as a focus for potential commercial Space Station activities. Awareness of the technological and potential commercial opportunities that a Space Station could present is planned through an outreach program that educates firms on the characteristics of space, identifies potential opportunities for commercial research, development, experimentation and production, secures appropriate NASA and aerospace contractor technical support and assists in obtaining appropriate NASA management and institutional support.

Another basic goal of the National Space Policy is the promotion of international cooperative activities in the National interest. Task Force personnel are in active communication with the European Space

Agency, the Japanese and the Canadians to assist them in identifying and defining missions having commercial potential in space and in delineating their requirements so that the Space Station can be designed to accommodate foreign as well as U.S. commercial requirements.

QUESTION MFA-35:

Inasmuch as unit costs of space equipment and services are so high as to weigh heavily on any space station procurement decisions (and, indeed, upon all civilian space activities), what steps are being taken to see that they are constrained, and even reduced?

ANSWER MFA-35:

A well thought out extended definition program, including identification of needed technology, before proceeding with a hardware development program will enable us to have a Space Station program that produces unit hardware less expensive both in its initial cost and operational expense than if we proceed with the development using current technology.

QUESTION MFA-36:

Given the relatively high cost of sustaining humans in space (even in low orbit, inside the radiation belts) in connection with the use of any such space infrastructure, what are the specific reasons for any plans to include them? And what are expected to be the values of any such costly employment?

ANSWER MFA-36:

The utilization of man in space is justified in a number of ways. There are numerous examples of specific situations where man's capabilities have been instrumental in salvaging space operations which have degraded or malfunctioned through unforeseen circumstances. These examples are found throughout our flight history and are prominent in Apollo, Skylab, and quite recently in the first flight of Spacelab. They generally involve a complex integration of man's intellectual, sensory, and motor skills. These situations are instructive in that man provides a capacity to deal with unforeseen circumstances which is not equalled by current automated systems. This is particularly true in scientific research where the details of the outcome are not entirely known. The following are typical functions which must be performed by man onboard the Space Station:

- Trouble-shooting and analysis of equipment operational anomalies not covered by built-in diagnostic systems.
- Physical removal and replacement of failed or otherwise inoperable systems components where this is desirable.
- Operation of teleoperated or telepresence equipment in unstructured situations.
- Handling and care of experimental animals and plants in

long space medicine and biology experiments.

- Set-up and observation of complex space-based experiments where robotic applications would be too complex for ready accomplishment.

- Reaction to anomalies behavior of experiments or observation of new phenomena not previously encountered.

RESPONSES TO WRITTEN QUESTIONS SUBMITTED BY CONGRESSMAN VOLKMER DURING THE HEARING BEFORE THE HOUSE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS ON FEBRUARY 2, 1984, TO MR. CULBERTSON AND MR. HODGE.

ADDITIONAL QUESTION MFA-1:

Please elaborate on the following:

a. How will a manned Space Station contribute to the maintenance of United States leadership and the other goals contained in our National Space Policy?

b. How will a manned Space Station best fulfill national and international requirements versus other means of satisfying them?

c. What are the national security implications of a manned Space Station?

d. What are foreign policy implications of a manned Space Station?

e. What is the overall economic and social impact of a manned Space Station?

ANSWER MFA-1(a-e):

President Reagan, in his State of the Union message delivered on January 25, 1984, directed NASA to develop a permanently manned Space Station within a decade. One of the basic goals of our National Space Policy announced by the President in July of 1982 is the maintenance of U.S. leadership in space. The permanent presence in space established through the Space Station initiative will sustain United States space leadership in many sectors. The Nation will reap the economic benefits of nurturing new industries that require a micro-gravity environment with the capability for manned intervention and interaction on a continuous basis. We will also be in a position to undertake new and important scientific endeavors such as assembling very large aperture antennas in space with the potential for uncovering puzzling issues with respect to the nature of energy, matter and the evolution of the universe. The Space Station, by virtue of its capability as a transportation node to higher energy orbits, will enable us to undertake an expansive new planetary exploration program. In the longer term, we will be in a position to initiate the exploration and exploitation of the solar system in the 21th Century. Thus, the advent of a permanently manned Space Station in low-earth orbit is a stepping stone to the 21st century that will assure the maintenance of United States leadership for the decade of the 1990's and beyond.

The Space Station, as currently envisioned, will have a distributed architecture wherein manned pressurized laboratories and unmanned scientific platforms will be parts of the overall infrastructure. This architecture is amenable to undertaking international cooperation in both the development and use of the facility. On this

basis, the Space Station will provide a vehicle to sustain and nourish our alliances with friendly nations.

The Department of Defense is on record as having no national security requirements for a manned Space Station. Nevertheless, the peaceful demonstration of our technological prowess will have a national security potential in the same manner that the Apollo program did in presenting visible evidence to the world of the capability of a free people. If a civil Space Station is developed, selected technology development missions with national security applications would be mission candidates.

To the degree that the Space Station is successful in nurturing new industries in space, such as pharmaceutical production, overall net economic benefit to the nation will occur. The Space Station development will not necessitate a substantial increase in NASA's budget. From this standpoint, therefore, it will have the same effect on the national economy as any other initiative that the Agency might undertake. However, the potential for profitability as a result of new industries in space has generated active interest both in the non-aerospace commercial sector and within other departments of the government.

ADDITIONAL QUESTION MFA-2:

Please elaborate on NASA's assessment of the relative merits of the following four scenarios for continuation of the Nation's manned space program:

Shuttle and unmanned satellites
Shuttle and unmanned platforms
Shuttle and evolutionary Space Station
Shuttle and fully functional Space Station.

ANSWER MFA-2:

Over the past eighteen months in the course of Space Station planning activities, various alternatives to a Space Station have been studied. These alternatives were studied in the context of the requirements for the types of space missions that are foreseen for the decade of the 1990's. The basic alternative scenarios studies were: 1) The Shuttle operating with free-flying satellites, 2) the Shuttle operating with unmanned platforms, 3) the Shuttle operating with an evolutionary Space Station, and 4) the Shuttle operating in conjunction with a fully functional Space Station. A brief discussion of each alternative follows.

SHUTTLE AND FREE-FLYING SATELLITES

This scenario is essentially "business as usual." It does not take the Nation significantly beyond the capabilities that exist today even if the on-orbit stay time and power of the Shuttle are extended by modifications to the Orbiter. This scenario does not satisfy the requirements identified for the missions of the 1990's, including

long duration manned microgravity laboratories for the development of commercial materials processing and life sciences research, a staging base for deployment and servicing of satellites at geosynchronous orbit, and a servicing/construction base for very large advanced telescopes and antennas.

SHUTTLE AND UNMANNED PLATFORMS

This scenario, including the Shuttle plus unmanned platforms serviced by the Shuttle, does have significantly increased capability over that of the Shuttle alone. This is true whether or nor the Shuttle has extended duration and power. The major factor in the improved capabilities is the platforms. These platforms are especially useful for long duration astrophysics and earth sciences missions. However, this scenario does not have the capability to fully develop commercial materials processing in space, geosynchronous satellite servicing, life sciences research, or very large structures construction. These types of missions represent new technologies and research for the 1990's and require long on-orbit stay time with manned interactions.

SHUTTLE AND EVOLUTIONARY SPACE STATION

This scenario assumes a Space Station can be built and serviced by the Space Shuttle in a manner which enables the essential elements of the station to be augmented over time, depending upon the demonstration that the need for such augmentations exists. A key feature of this concept is that there is a valuable set of missions which will be accommodated within the Space Station's baseline set of capabilities. If and when the need arises, the Space Station could be expanded to permit larger crews, added power and laboratory modules, as well as deployment/servicing capability for spacecraft in geosynchronous orbit. The baseline set of capabilities would provide for accommodations for a crew of six to eight, 75 kilowatts of power, two laboratory modules, two platforms, and low-earth orbit satellite servicing capability. The baseline capability of this approach was selected by the President as being the appropriate level of commitment to a Space Station.

SHUTTLE AND FULLY FUNCTIONAL SPACE STATION

This scenario assumes that the evolutionary capability of the Space Station is fully exploited at the outset with all modules and equipment developed and placed on-orbit as fast as possible.

Commercial materials processing is developed in a continuously manned on-orbit laboratory and potentially in commercial modules attached to the manned base. Satellites are launched from the station to geosynchronous orbit (GEO), satellite spares are stored on the station for immediate deployment in case of failures in GEO orbit, and GEO satellites are serviced via an orbital maneuvering vehicle deployed from the Station. Astrophysics missions are accomplished on the manned base, the platforms, or on free flying satellites; very large telescopes and antennas are constructed at the manned base before deployment on the platforms or as free-flyers, and both the platforms and the free-flyers are routinely serviced. The nominal mode of operation is to refuel, repair, or reconfigure telescopes and other instruments on-orbit rather than to discard them. The long duration effects of weightlessness on plants and animals, including man, are studied and countermeasures for any detrimental effects are developed in a life sciences laboratory. Planetary missions are staged and launched from the station.

Mr. MACKAY. Mr. Nelson, do you have any questions?

Mr. NELSON. No questions.

Mr. MACKAY. Mr. Lujan?

Mr. LUJAN. Yes. Can you build it for $2 billion? [Laughter.]

That question may be propounded facetiously, there are some thoughts that run through my mind always on research that we have to go and do it our way, the not-invented-here syndrome. You do not even think, "Well, Mr. Rogers is correct. We have the technology." I have seen those tubes that you put together over at Langley. The thought goes through one's mind, "Well, the Salyut is working. They steal our plans all the time. Why can't we steal theirs and modify them." Those kinds of thoughts that maybe there is a lot of truth in what Mr. Rogers was saying. What about that?

Mr. HODGE. Let me try to answer it in my way, and Phil can do it, too, in another sense. The first time I met with Mr. Culbertson and Mr. Beggs, when I came back to NASA and started to put this team together, I was given a number of guidelines. One of them was, you are going to have to look at the way we do business, because we have to involve industry more, we have to think about the international community, and we have to look at the way we manage, as far as cost is concerned, and see what we can do in an institutional sense to make those changes.

We have done that, and we have spent a lot of time worrying about that. And I think we are going to perform in much the way that Mr. Rogers was talking about. In fact, if you read the letter from the Space Science Board by Dr. Donahue, he said, in fact, we were already doing that, despite the fact that he felt he could not support the space station on the basis of science alone, and that was the way the letter was written. He felt that we were, in fact, pursuing the requirements in a proper way, and that we were working with the customers and we were thinking about them.

Can you build a space station for $2 billion? Well, what we did was to invert that question. We said, "What is it we are likely to want to do in the year 2000, and what is it we are likely to want to do in the year 1990, and what do you need in order to do that?" It was as a result of that examination—and we spent a full year on that examination—that we determined something like this, with the capabilities of this, that would cost in the aggregate about $8 billion. Sure, we could have gone somewhere else and said, "Can you design something different for less money to do less?" But I think that is not a very good way to ask that question. You have to ask it in terms of what do you want to do.

The question of whether you can take some of that $8 billion and have somebody else build it is a different one and one that we have to address during the next couple of years, during our design process. We intend to do that. Mr. Beggs said yesterday, "It is my personal belief that at least one of those modules in the initial operating capability will be provided, designed, and operated by private capital." I do not think there will be much more than that, because I think somebody is going to have to—you know, great American industry is fine, but it has to be proved that there is a return on investment there, and they are going to let somebody else have the first go at it.

But we will get one, I am pretty sure. There will be pieces that are supplied in collaboration with our foreign partners.

Mr. NELSON. Will the gentleman yield?

Mr. LUJAN. Certainly.

Mr. NELSON. Basically, as I understand your approach as you outlined it there on the screen, you are basically doing intensive engineering and research. So in the question that has been raised earlier, when I was not here, by Mr. Rogers, could you answer those questions by saying that at the end of the 2-year period, we will have enough data from the engineering so that if we concluded it was not worth the cost, the project could be terminated at that point. Is that true?

Mr. HODGE. Yes; that is true. I do not think that will happen, but that is true.

Mr. CULBERTSON. Mr. Nelson, can I expand on that just a moment? In the cycle that the Government goes through, we get in a situation where we must come and describe to you what it is we choose to study and define, and we must price that to you, our best estimate, and that is appropriate; but we must do that before we study it in sufficient depth to have a great deal of confidence in that particular price. That is what this process is all about.

This committee, I believe, asked 3 years ago for NASA to study how we could better estimate our prices and our schedules and control the development schedule a little bit better. That study, done by Don Hearth, has been widely quoted. But he said one important thing was for us to do a good enough job in the preceding years, before we started to do detail design and cut metal, that we could do a sound job of estimating to you what the price was going to be, what the characteristics of the system would be, and what the schedule would be to which we can deliver. We are just getting ready to do that.

So your statement, "Where are we on this," is precisely correct. And I think you should ask us, as we do this definition study, and certainly as we come to the end of it, to define for you with some precision why we think it ought to be like it is and what we think it will cost and what we think the schedule will be. That is the only way we can mutually arrive on what the system should be and what it will cost.

Mr. NELSON. And just as a statement, Mr. Rogers on page 8, had said most articulately that over the next 2 years this time should be used by both branches of the Government to decide upon and articulate the space goals and objectives. I think that we might have a concern, Mr. Chairman and Mr. Lujan—and thank you for the time—that you get another camel's nose under the tent, and you have another Government project that starts a momentum of its own. There is certainly that in every Government project that is undertaken. Nevertheless, NASA's projects are highly visible, highly profiled, and if it cannot measure up, then it is going to be our job as well as yours to make sure that it can measure up. Given the competition for the dollars that are going to start coming along in 1987 fiscal year, when you would have to start bending the hardware and the dollars would start going up, this project is going to have to withstand the cross-questioning, and it is going to have to stand on its own fours on merit.

Thank you, Mr. Lujan, for the time.

Mr. LUJAN. If I may proceed, the big fight that we are going to have in this committee—and I can see it shaping up already—is to shave out of that $150 million to put it into shuttle production. Everything has to have a little give, I suppose, and maybe that is not a very fair question to ask you. Mr. Beggs said yesterday, it would certainly throw our scheduling out of kilter. But where would be, if you can tell us, the bottom line of how much of that we might divert?

There is a real dilemma on the part of the members of this committee, including myself, as to whether four is enough—we have no backup capability if something should happen to one of the other orbiters—and whether we should move on ahead. If we do not move on ahead, shutting down the supply lines, the production line, and those sorts of things. We would like to be able to accommodate both, but the money is not there to accommodate both. You look like the prime candidate for a little fleecing.

Mr. HODGE. I would like Phil to talk about the fourth or fifth orbiter, but the reason I am sitting here grinning is that I went through a similar question about 8 weeks ago, and a similar question about 8 weeks before that, and a similar question about 8 weeks before that.

Mr. LUJAN. But you did not know it was $150 million. You had an idea what it would be, but you did not have a flat figure that we could talk about at that time.

Mr. HODGE. That is right. It was 8 weeks ago when I got a telephone call at home from Mr. Beggs. He said, "How low can you go?" I said, "$175." He said, "Where will you drop dead?" I said, "That's where I drop dead." That was in order to meet the schedule we were talking about at that time.

Mr. LUJAN. So you are behind?

Mr. HODGE. What we did was, in order to come to the conclusions we have right now, to slip the schedule 4 months essentially. That means, we are going to bring our major contractors on board toward the end of February. That is going to be a long, dry wait for them. One of the problems you have in starting a program like this is, you have to develop the right kind of momentum with the right kind of people. It is sort of a joint venture between industry, Government, and the universities. The management problem is really bringing those people to peak at the right time so that you can continue on with the thing.

I believe that the biggest problem associated with the dollar level is how far dare we let that slip, that momentum, before we lose a lot more time or we do something dumb. That is the biggest problem right now.

Mr. CULBERTSON. I think there are a couple of additional factors that need to be considered. They are similar in tone to what John has said. There is some level beneath which it will be very difficult for us to talk seriously with the international community about their collaborative effort, because the program will go too far beyond their ability to have continuity in their planning.

I think it is not possible for us to say at what point does the system not make any sense. At what point do we say, "Let's call it all off for another year," or something like that. John has bled a

great deal during the last 3 or 4 months, and I think that the balance between analytical studies and the technology effort which he proposes is exactly what is needed for a program like this. It responds, I think, to the kinds of concerns that Mr. Rogers was talking about earlier. It is, however, a matter of schedule in the maintenance of the program, both with respect to the NASA and the industry, and perhaps more importantly, this country and the other countries that might cooperate with us.

Mr. LUJAN. One of the concerns is the effect on unemployment as you shut down those production lines. Mr. Beggs said yesterday that you wouldn't begin to see that for 2 or 3 years with the spare parts program. Maybe coincidentally, the production of the space station begins around that same time. Are we talking about the same numbers of people needed in the space station project as we are in the shuttle project?

Mr. CULBERTSON. During its peak years, I would expect that the number of employees by the principal contractor probably is of the same order of magnitude as those which have been involved in the design and development of the shuttle, yes.

Mr. LUJAN. Thank you.

Mr. MACKAY. Mr. Nelson?

Mr. NELSON. May I offer an editorial, Mr. Chairman?

Mr. MACKAY. Certainly, and you do not even have to end it with a question.

Mr. NELSON. We do have a little more leeway here than we had in the State legislature, don't we?

I would just like to say that yesterday I called Mr. Beggs not only an excellent administrator but I used the term "magician." I did that with a great deal of affection because, Mr. Lujan, what he has been able to pull off, with all of his fights with OMB and other areas within the administration, is to get the commitment—which is the big difference between when that question was addressed to John 8 weeks ago and now. In the interim, the President has made the commitment, and it is out there. What Beggs was able to do is keep alive the fifth orbiter option with those spares, to the tune of about $500 million, which he says is going to about $600 million next year.

Now, I would like to see more, as a person who thinks that it is inevitable that we have to have a fifth orbiter. I would like to see more, but what he has done is a very delicate balancing act of keeping his option alive and at the same time moving ahead. Again, I commend the leadership in NASA, under the fiscal and political constraints under which they are operating, for they have again pulled a rabbit out of the hat.

Mr. CULBERTSON. Let me point out that we spent an awful lot of work analyzing that whole proposition that you have just laid out, Mr. Nelson, to make sure also that in trying to achieve that ability to support both programs with spares and perhaps the eventual building of the fifth orbiter, to not neglect the other parts of the program which are so important. The science program is very much alive and healthy, as I am sure you will be convinced when Dr. Edelson comes up and talks to you. The technology program is strong and healthy. We made sure that we did not ravage any part of the program in order to try to fit that balance together.

Mr. LUJAN. It is going to get harder.

Mr. MACKAY. I would like to ask some questions, and I will start out by giving the opposite of the disclaimer that Mr. Nelson gave. These are not editorial questions. I would like to see us develop the space shuttle. As Dr. Rogers suggested, I don't want to be drummed off the committee for asking questions. However, I think there are questions that I think this committee has a responsibility to ask.

If we do not have the money to do everything we want to do, can you design this so that you can do parts of this, and can you set up priorities, and can you give us a baseline by which we can evaluate and even go so far as to talk about cost-benefit ratios? I do not believe you can do that unless you tell us more specifically than we have been told thus far what are the goals of your program. I do not see how we can evaluate a space shuttle unless we know what we are trying to do. Does it fit in with a lunar exploration program? Is that why we are doing it?

I assume we have evaluated unmanned ways of doing this which would be substantially less expensive and have determined that there is some reason that we have to do this. If so, I would like you to articulate what that reason is. If this is premature and we have to wait another year, I would like to put you on notice that somebody has an obligation to answer that kind of question. I am as excited about the program as you are.

Mr. CULBERTSON. I think the points that you have made are exactly right. The questions are totally appropriate for this committee. If my earlier comments on the OTA discussion seemed to say that we should not be doing those things, then I stated them incorrectly or I was misinterpreted.

It is important for us to answer the kinds of questions that you are asking. The only one that gives me a great deal of difficulty is one that we have examined for the last 15 years anyway, and that is the cost-benefit analysis of a manned versus an unmanned system. There are all kinds of analyses that can be made. I do not know how to do exactly what I think you are asking to do, and I do not think that it is possible to come up with a true cost-benefit analysis of a manned system versus an unmanned system.

Our approach in thinking about this has been that we must automate where we possibly can, and where it will be of benefit to the system, we should advance the technology, the robotic technology, and the technology associated with artificial intelligence even. Clearly, if a crew of six to eight people is going to be effective, it is going to need an awful lot of assistance by having things run by themselves. NASA I think has done a fairly decent job in the past of trying to balance between manned and unmanned system. There are advanced technologies in robotics and in automation through many of our programs, and we will continue that and intensify that in many areas in the space station. But all the questions you ask I think must be asked, and I think it is up to NASA to try to answer them. I am not sure how we can answer the one on the cost benefit of man's presence in space.

Mr. MACKAY; Did you see the manned space platform as a necessary ingredient to further lunar exploration or interplanetary?

Mr. CULBERTSON. The last of the specific things that I mentioned in my opening statement on the characteristics of the space station

would be that it would be the necessary precursor, I believe, to most of the more advanced things that this country will think about in the year 2000. That would include a return to the moon. Clearly, the space station that we are talking about is not necessarily a link in the direction of more complex lunar exploration or a colony on the moon. But equally so, it is clear to us that if the United States does decide to go back to the moon, then it will be necessary for us to have a significant capability in low-Earth orbit, if we are to get back to the moon efficiently.

But the system that we would propose to you to be in this increment which we refer to as an $8 billion increment has a total capability all by itself. It is not linked irreversibly to any future direction that we might take in our present concept. It is linked loosely to practically every future direction that we think this Nation's civil program might choose to take in the kind of national debate that Mr. Rogers talked about.

I do not know that this answers your question.

Mr. MACKAY. You see, I am still trying to articulate the question. I know something about the oversight function, and I see beautiful models and well-prepared exhibits, and I realize that has to do with advocacy in the oversight function. It makes it easier not to ask the tough questions because it is easy to get very enthusiastic. Let me just tell you what I think the questions are that we ought to be asking. Then maybe in the next 2 years, since we have that time, we can better define the questions as you better define the answers.

If this is justified in part by military considerations that part ought to be in the military budget. That is one of the questions.

Mr. CULBERTSON. I will give you the answer right now. We in NASA wholeheartedly agree.

Mr. MACKAY. I do not see you as being in control of that decision. I see you as being a captive, who is being told, "If you want a space station, maybe you ought not to raise that question."

Mr. CULBERTSON. We have raised it.

Mr. MACKAY. I also favor the military, by the way.

Mr. NELSON. Would the gentleman yield?

Mr. MACKAY. Yes.

Mr. NELSON. I have been frustrated with the military as we have seen this thing develop. They say, "No, we do not really want to be part of the space station, and therefore we will not offer any dollars." I think we are all agreed here that if there is a part that is going to be allocable to defense, it ought to be in the defense budget. So they really have not helped up to this point by saying, "OK, we want it."

But you watch. We get on and start moving toward a space station, it is going to become apparent that there will be part of it that will have a military application. At that point, it is going to be our responsibility, I think, to make sure that the dollar costs are allocated in the right ways, even though the Defense Department has not embraced this project thus far because they did not want to spend the money for it. Is that a fair statement what I just said?

Mr. CULBERTSON. It is not fair; it is excellent.

Let me go one step further, though. We have had a detailee from the Department of Defense, in the Air Force, working with John

and his task force ever since we got this started. They are totally aware of what we are doing. We have encouraged them to give us any requirements that they might have so we can think about them from the beginning. It is much easier and less expensive to incorporate a requirement at the front end than it is when you are halfway into the design of the system.

Congressman Nelson points out very correctly that to date they have said, "We will keep watching you, but we do not have any requirements." However, what you say is also true. We will develop, I believe, a national asset. It will be a laboratory in space. Among other things, it will be a laboratory in space. We are trying to design it so it can be fairly versatile in the kind of research that it can do. But all of the requirements that we are trying to incorporate in our statement of capability for the system have come from several users.

In all probability, those capabilities will be very similar to what the DOD might have given us if they had given us anything. We will continue, obviously, to make our studies known to the Department of Defense and the direction in which we are going. We share the same concern that you do, and I think it is totally appropriate for the Congress to help us make sure that NASA has the responsibility for the civil requirements for a system like this, and if there are other requirements they should be shouldered by someone else. In a collaborative effort or whatever, they should be shouldered by someone else.

Mr. MACKAY. Mr. Chairman, I want to congratulate you and the staff for putting this agenda together in the fashion it is put together. I think one of the prototype efforts that really needs to be put forward is the congressional use of OTA. I think this is a fine first effort, and I think we are going to be able to benefit from being able to explore the use of our own arm to help develop the policy questions that need to be raised. It really concerned me yesterday or when we met with Dr. Keyworth that we find ourselves in a situation where 65 percent of the U.S. research budget is military. We find ourselves where there is an obvious correlation between our falling back in terms of productivity and in terms of loss of market share, and the fact that we are not putting into civilian research as much as the people we are competing with.

I found it very disturbing that it was impossible to discuss that question candidly with the President's scientific advisor. I find it refreshing to find someone willing to say, "We ought to determine what our goals are in space before we commit $8 billion." There are some very hard-headed people on the other side of the table worrying about what our goals are, and I think they have already made that determination. The hazy goals are hazy on purpose.

I am not saying that in terms of NASA. I think you all are trying to do the job you are created to do. But for my part, I think we ought to have a direct discussion of goals, and we ought not to put up the money until there is an agreement on what we are trying to do. That is the end of my editorial.

Mr. CULBERTSON. May I add something to that from NASA's standpoint?

Mr. MACKAY. Yes, sir. There is room on the editorial page.

Mr. CULBERTSON. We have faced the issue that you are discussing many times. Some of you are familiar with what we have referred to as the outlook for space study which was done in the midsixties. I was on that committee, and we were chartered to look at the next 25 years of civil space. Twenty of us worked pretty hard for most of the year, trying to come to grips with exactly the question you have. We were all NASA people, but we were drawn from every facet of NASA. There were only two of us that had any experience in the manned space flight program, incidentally, who were on that team.

Don Hearth was the chairman of that committee, and I talked to him this morning. I said, "Can I refer to that committee and what your point of view was as I discuss it this morning?" "Certainly," he said.

It was interesting the way that evolved, because Dr. Hearth said, "Tell them that as we began that, you, Phil, are the only one who thought there was major significance in the manned program for the next 25 years, and that included the chairman." Don had grown up in the planetary world, and so far we do not see any manned role in the planetary program. But he said, "Tell them that the 13th conclusion—'That the United States should develop a permanent space station to fully exploit the zero gravity environment of space for basic research to develop a full understanding of the ability of man to work and live in space for extended periods and to provide a potentially usefully instrument of U.S. foreign policy'—was unanimous in the opinion of those people after the year's work."

I do not think that necessarily adds anything to our position today. But, we work at the problem you are talking about, what should be the national goals in space. I think that the idea of anything we can do to stimulate, foment if you will, or anything else, a national discussion of this issue is very healthy. Please do not ask for a consensus, however, because you are not going to get it. And Tom, you will not get it either; I wish that you could, but you will not.

We have, within the last few months, put together another NASA activity looking at the next 25 years. This is internal. We are an organization that has many advisors and we will consult with our advisors, but in the final analysis it will be a NASA input to this national debate. I think it is very important that it be held. I think that Tom did an excellent job of gathering people from outside the aerospace community in this debate, and we look forward to it very much. I think you should hold us to properly relate to that debate when it is over. But I guess I also have to say "if it is over." It is going to be difficult.

Mr. LUJAN. Referring to one of the questions that the acting chairman had, we have to be very careful that we do not hang a cost-benefit ratio formula to it because what is it worth in one of those goals to understand the effects on man when you are out there. That you are not going to be able to quantify or put so many dollars on. But eventually, it will have some benefits. It is very difficult to go ahead and try to hang a cost-benefit ratio formula on something like that.

Mr. CULBERTSON. I think that is one of the things that Mr. Webb had in mind when he talked about the significance of man. It is what captures the imagination of this country. I do not know what the capturing of the imagination of this country is worth. I think it is terribly important to capture the imagination of our young people, and I am convinced that the manned program has done that very effectively. Certainly, the unmanned program has done a good job of it, too. But in my contacts at the university level and lower, it is clear that many people are stimulated to excellence and stimulated to move into the high-technology areas because of what we are doing in NASA and in particular in the manned program.

Mr. LUJAN. On capturing the imagination, let me say that yesterday I was driving home with a student at GW. One of the questions that she asked me about the whole space program—she is a physics major—about what were the possibilities of being an astronaut and those sorts of things. I said, "Do you have some interest in that?" She said, "Perhaps." Capturing that imagination means, "Crack the books." That means 1 million students that might be a little better than they would normally if they did not have that goal in mind, or maybe tens of millions, or who knows how many. That I guess is capturing the imagination.

Mr. CULBERTSON. Certainly. And how much is that worth?

Mr. LUJAN. Invaluable.

Mr. MACKAY. Are there other questions or comments?

Mr. Chairman?

Mr. VOLKMER. Yes, I have some questions. I am sorry I have been away, Mr. Culbertson. I do not know what areas you have covered, but if you have, just say so and I can get back to staff and work it over. I am concerned about a couple of things.

As I mentioned yesterday when we had the administrator up here, the concept of a space station is just one concept. It may not eventually evolve into that, but it may be, and we do not know yet. But how long do you envision that a space station—let us say we do use a modular system, with the solar arrays and so on for the first part of it, and we have one up by 1991 or 1992—how long do you envision that those modular parts and solar arrays would last before they would have to be replaced?

Mr. CULBERTSON. I am not trying to skirt the question at all. We are planning to design it so that we can change the systems out in orbit, add upgrades based upon new technology, or expand the capability, or if they are failures by replacing things. We think it is very realistic to think in those terms.

A lot of people say that space is a terribly hostile environment. In fact, space is a very good place to store things and to not have them corrode and wear out I do not think there is any way to say how long pieces of that will remain as a basic part of the infrastructure of a manned system. We will not design it for obsolescence; we will design it for upgrading. It is ridiculous for me to say it will last forever, but I do not think there is any way we can say that it will be shorter. I would think that technology will overtake the kind of system which we will develop probably 20 years after we launch it.

Mr. VOLKMER. One reason I brought up this question is that the Russian space stations have had what I consider in space a fairly

short life or permanence in space. I hope we envision that our space station that we envision, at least the modulars, the basic structures, will have a longer life, and those total structures would not be replaced every 3 to 4 years.

Mr. CULBERTSON. It is certainly our intent that the structure will be designed for infinite life. That one we can say. We also have an advantage that the Russians do not today have, and that is that all these pieces will go up in the shuttle, and all of them can be returned in the shuttle if a major overhaul is necessary.

Mr. HODGE. On that question on evolution, I did have something to show you, and I would like to do it, if I may. These are the solar cells [indicating]. There is another way to get to the same problem, and that is with these [indicating], and this is what is called a solar dynamic system. It mounts a little jet engine in the back. Those two do the same as that, and they can be put on for a second instrument.

Mr. NELSON. They do what?

Mr. HODGE. They heat salt up in here, which runs a little jet engine in the back here and then provides the same power.

Mr. CULBERTSON. They are an alternate source for the basic conversion of solar energy into electrical energy.

Mr. HODGE. We can put those on there as the second instrument power rather than these.

Mr. VOLKMER. Another question I have needs to be addressed as we go down the road with this year's authorization. There has been proposed $150 million for 1985 for study, design, and so on. What would be the impact if that were reduced, either by one-third or one-half? What would be the impact on the design and studies ongoing?

Mr. CULBERTSON. I was asked essentially that same question earlier.

Mr. VOLKMER. It has been asked already then?

Mr. CULBERTSON. Well, I did not answer it. [Laughter.]

Mr. VOLKMER. Some of us would like to know what is going on when it happens. I am sure that somewhere along the line, something like that may be proposed. Therefore, some of us would like to know what you envision the result of that would be.

Mr. CULBERTSON. The sort of answer I gave before was about as close as I am able to answer it with any precision. The fundamental thing that would happen would be to affect the schedule. That is the clearest, most obvious thing. We have drawn this as tight as we can get it and have maintained the kind of a schedule which would have contractors on board sometime in fiscal year 1987 to begin the detailed design. What happens if this is cut back? Yes, it will affect the schedule we are working on. There is some level below which it will be difficult for us to maintain the continuity and the momentum which we have in the work that is going on today, which may or may not be important. But we do have a significant momentum, both within NASA and in the industry.

Perhaps most importantly, there is some level beneath which it will be very difficult to attract the real interest of the foreign community. I do not know what that number is. And as I said, I did not answer it, and I do not know how to answer that question. Clearly, the program would not stop if it is cut. Certainly it will

suffer from the standpoint of schedule and the success which we have in attracting both the private sector for its investment and its involvement and the foreign community. Is it a disastrous effect? Of course not.

Mr. VOLKMER. In your studies so far, have you evaluated the need or the non-need for extended orbit time for the shuttle prior to having the space station in orbit?

Mr. CULBERTSON. We spent a fair amount of time thinking about it. Let me answer your question in two ways. We spent time thinking about things that we want to do with the shuttle to test the technology that we will be developing for the space station. To date, we have not found any requirement for that sort of test in the shuttle which would require mission duration longer than the 10 days that fundamentally is within our capacity today. The thing that we could get with longer duration with the shuttle would obviously be more test in time.

Things need to be tested in two ways. We first need to test whether or not a system designed on Earth will work in the absence of gravity, and that is not a life test, that is not a reliability test, that is fundamentally a test of the design concept. We can do that in a fairly short period of time on the shuttle. The other kind of testing has to do with reliability and lifetime, and 30 days will not do us much, 30 days as a possible increased capability for the shuttle will not do much for us in understanding fundamental lifetime or reliability of systems. So we will have to approach that in some other way.

The other way that we will use the shuttle is, I believe the shuttle—and in particular the shuttle/spacelab combination—will go a long way toward getting the using community—I am thinking of the scientific community and all the other users—to understand how most effectively to use man in situ with the work and in combination with people on the ground. Mr. Beggs mentioned yesterday that there were some marvelous things that happened during the spacelab mission, where we could see what was going on in the interaction between the men in orbit and on the ground.

I think it is important that we continue that so that when there is a space station, people are ready to take maximum advantage of the capabilities that it would offer, and we would like to use the shuttle that way. Once again, use of an extended-duration orbiter can get us more data, but we see very few things in which there is any kind of an incremental change in how it can be used. We get more, but we do not get something new by this extension.

Mr. VOLKMER. Have you determined the high-risk technologies that would be associated with a space station development?

Mr. CULBERTSON. John, do you want to answer that?

Mr. HODGE. I am really very pleased where we stand, as far as our knowledge of what technologies are available within the Agency and what we think we need. It is for that reason that a large percentage of the budget is, in fact, in the technology area and will be for the next 3 years.

Mr. VOLKMER. Could you furnish to the committee those areas we still need to develop, as far as determinations yet to be made?

Mr. HODGE. Yes, we will do that.

Mr. CULBERTSON. May I suggest that the word "high-risk" is not really the operative word. We have said that there are advances in technology which will improve the efficiency or the effectiveness or a variety of improvement kind of things. But we have also said that there are no long poles with respect to high-risk considerations. Is that fair?

Mr. HODGE. Yes, that is fair.

Mr. VOLKMER. Ignore the high-risk then and just give us the technologies that still need to be developed further. I would appreciate that.

Mr. HODGE. Yes.

[The information follows:]

Over forty percent of the planned FY 1985 budget is for developing the technologies we believe are necessary to provide us with a space station with improved efficiency and effectiveness. Work has been planned to focus these technologies to a space station application, building and integrating prototype components into subsystems for demonstration of promising technology options in ground based test bed facilities, and conducting flight experiments through the Space Shuttle. A list of the candidate technologies for further development follows:

By Technology Discipline

o Power:
- High Capacity Energy Storage
- Improved Performance Solar Arrays
- Fuel Cell Electrolysis
- Automated Power Subsystems
- High Voltage/Power Components
- Bulk Power Transfer

o Environmental Control and Life Support:
- Extra Vehicular Activity - Suit
  Mobility Aids
  Tools
- Crew and Work Station Accommodations

o Auxiliary Propulsion:
- Low Thrust Gaseous Hydrogen/Oxygen Auxiliary Propulsion System Components
- Cryogenic Fluid Resupply
- Cryogenic Fluid Management
- Electrothermal Thruster System

o Data Management:
- High Speed/Capacity Data Systems
- Fault Tolerant Systems
- Bubble Memory Systems
- Adaptive Data Networking
- Software Management

o Structures/Mechanisms:
- Advanced Materials for Active/Passive Damping, Coatings, and Films
- Rendezvous, Docking, Berthing Systems
- Advanced Mechanisms
- Structural Concepts, Dynamics and Analysis for Large Solar Arrays

o Thermal:
- Integrated Thermal Utility/Thermal Bus
- Maintainable/Replaceable Radiator
- Long Life Heat Rejection
- Versatile Thermal Acquisition and Transport

- o Human Capabilities:
  - Habitability Requirements for Extravehicular and Intravehicular Activity (EVA and IVA)
  - Man/Machine Function Allocations
  - Human Interface to Intelligent Systems
  - Direct, Supervisory and Automatic Control of Teleoperators and Robotics
  - Orbital Maintenance Methodology
  - Medical Aspects

- o Attitude Control and Stabilization:
  - Predictive Methods for Large Spacecraft Response
  - Integrated Analysis Methods
  - Advanced Guidance and Control Components
  - Large Momentum Management Devices

- o Communications:
  - Multiple Use Antennas
  - Infrared Communication Systems
  - Accurate Ranging and Tracking Systems
  - 60 Gigahertz Devices/Components
  - Vehicle-to-Vehicle and Vehicle-to-Station Communication Systems

- o Systems/Operations:
  - Autonomous Systems
  - Hierarchial Control
  - Self Diagnosis/Repair
  - Integrated Crew and Life Support/Energy Management System Development
  - Attitude Control/Energy/Crew and Life Support System Development

Mr. VOLKMER. I suppose you have addressed the question of international development and how we are going to work that in?

Mr. CULBERTSON. We addressed it some. I think Mr. Beggs mentioned it pretty well yesterday.

Mr. VOLKMER. I am sure you will have to participate with Mr. Beggs in that, as we go down the road, to try and get international cooperation and also private enterprise in this country.

Mr. CULBERTSON. Both of those are very important to the effective success of this program. We will be working very closely with the kind of directions that Mr. Beggs will lead.

Mr. VOLKMER. I had to walk out when you started to answer Mr. Rogers' statement on the "classic" contracting, but I will get that later.

Mr. MACKAY. This has been very helpful, very thought-provoking, and I very much appreciate your participation. We will assume this is the beginning of a dialog. Do you have any further comments?

Mr. CULBERTSON. Just to express our pleasure at having the opportunity to discuss it with you and also look forward to those times when we can describe it in more detail to you as time goes by. Thank you for the opportunity.

Mr. MACKAY. Our next witness will be Dr. John Martin, Associate Administrator of the Office of Aeronautics and Space Technology of NASA.

Mr. VOLKMER. Dr. Martin, I first want to commend you on your recent appointment as associate administrator, and I look forward to your testimony for the first time today, and I am sure quite a few other times in the future before this subcommittee.

I understand that you have a prepared statement, and that prepared statement will be made a part of the record. So you may either review it in total or summarize however you so desire. You may now proceed.

STATEMENT OF DR. JOHN J. MARTIN, ASSOCIATE ADMINISTRATOR, OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY, NASA, ACCOMPANIED BY DR. RAYMOND S. COLLADAY, DEPUTY ASSOCIATE ADMINISTRATOR, OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY, NASA

Dr. MARTIN. Mr. Chairman and members of the subcommittee, thank you very much for those kind words of welcome. They help a lot this morning.

I was going to ask you to put the formal statement in the record, and I appreciate your permitting me to do so. I do have some remarks that I will make toward the figures that exist in the formal statement that you have. I would like to begin by saying, however, that although I have been the Associate Administrator for Aeronautics and Space Technology for a very short time—which is another way of saying I am still laboring with a lot of innocence with respect to details of the program—I have had a substantial interest in NASA for quite some time.

During my tenure as Assistant Secretary of the Air Force for Research Development and Logistics, I was aware of the considerable importance of NASA programs and, in fact, cooperated very closely

with NASA in quite a lot of work that was going on in those days. So I have a high regard for the research itself and for the resulting technology contributions to both civil and military applications of space.

I know that the support and guidance that comes from this subcommittee has been and will continue to be vital to the success of the activities that we are going to describe to you. I have with me this afternoon my deputy, Dr. Raymond Colladay, whom I will call upon from time-to-time, if the answers are too difficult for me. What I have to say is in four parts. I have some introductory remarks connected with some slides. Then I will talk about some major programmatic thrusts which we have—there are three sections of that—and then I have some closing remarks. It will take me about 20 minutes, Mr. Chairman.

The major emphasis (fig. 1) of the 1985 space research and technology program continues to be on the development of long-term enabling technology in support of U.S. space efforts, civil, commercial, and military. I might say, with more emphasis day-by-day in the commercial applications of space. The program is generic in nature, with long-term focus on needs of transportation, spacecraft, and platform systems. Those three are our major programmatic thrusts. Our goal is to make substantial contributions toward maintaining the preeminence of the U.S. in space. Of particular note are the contributions to the technology options we have made in providing the Space Station initiative announced by the President in his State of the Union address. Just a few are fuel cells, batteries, life support systems, heat pipes, thrusters, and that just begins the list.

[Figures 1–14 appear at the end of Dr. Martin's prepared statement, see p. 185.]

The 1985 space R&D budget request is compared here (fig. 2) with fiscal year 1983 and 1984. Our budget request is for $150 million, a 9 percent increase over 1984. The major focus of our efforts continues to be in the seven research and technology base activities that are characterized by the research on long-term, high-risk, high-payoff technologies. The budget also includes $4.9 million to continue support of the standards and practices activities of the chief engineer's office. But, the one important resource in our program is the research staff at the NASA centers, which would grow modestly, as you see, by about 1 percent in the proposal that we have.

The next chart (fig. 3) gives the distribution of funds by technical area. The budget request here is broken down into the seven disciplinary areas and descriptions of the work that goes on in each of the seven areas is described in the narrative budget materials. So I will not go into details at this point. There are, however, some key growth areas in the research and technology base, specifically reentry technology, which would increase by $1 million; human factors programs, growth by about a half-million dollars; and space flight experiments, one structures technology experimental program called STEP, an addition of $3 million, and cryogenic fluid management increased by $3.5 million.

The systems research portion of this chart supports a number of activities, a few of which are in-space flight research and orbiter

experiments. Another is ground test of advanced LOX/hydrogen propulsion system components to increase life and reliability. Also multidisciplinary research focused on our three major thrusts in transportation, spacecraft, and platform systems, and also systems studies to define technology requirements and to match them with the technology opportunities for substantial improvements in the future.

Finally comes the distribution by the centers of NASA (fig, 4); Approximately 54 percent of the research and development budget is conducted in the three research centers that I am responsible for. These utilize centers of excellence in disciplinary research. Those are the ones at Ames and Langley and Lewis. Ames specializes in thermal protection, aerothermodynamics, and infrared detection; the Langley center in structures and dynamics, systems analysis, and control systems; and Lewis center in chemical propulsion, communications and power.

The remainder of our work is at space flight centers to capitalize on the particular technical expertise which they have, the facilities which they possess, and also to provide transition of laboratory and research work to systems applications.

I will begin now with the three major programmatic thrusts, the first of which is transportation. We will continue our research directed at space-based orbit-transfer vehicles. Studies indicate that a reusable OTV will significantly reduce costs in transferring satellites from low earth orbit to geosynchronous orbit. We are working on three key technologies which you see in this chart (fig. 5). One is aerobraking, another is cryogenic propellant management, and the third is propulsion component research. We will continue to perform wind tunnel tests and evaluation of the aerobrake configurations. They offer the opportunity to reduce the amount of propellant required for the return of the reusable orbital transfer vehicles to low-earth orbit. This, of course, translates into greater payload capability, something to be sought after.

In the coming year, we would begin development of flight hardware which would be used to validate concepts and analysis methods for cryogenic propellant management systems. This would enable on-orbit refueling of OTV's.

Our propulsion component research program will be directed toward improved understanding of thrust chamber and turbo machinery performance so that we will have more efficient operation of the OTV engine.

The next area (fig. 6) deals with highly maneuverable reentry vehicle research, which can provide considerable increase in entry flexibility for enhanced mission capabilities. Our program would extend current capability in entry research for the prediction of entry response to these future high lift-to-drag ratio configurations. Wind tunnel tests will be performed to develop and validate the aerodynamic and aerothermodynamic performance of the initial concepts. We will continue to evaluate concepts for internal tankage, primary structure, and thermal protection systems.

In the chart before you, the tankage is the internal metallic structure and is the primary load-bearing structure. It supports an external aeroshell which also provides thermal protection from aerodynamic heating. Flight testing will be necessary to verify per-

formance because of ground-test limitations. The definition of a flight research vehicle for entry would begin in fiscal year 1985.

My final chart (fig. 7) on transportation deals with LOX/hydrogen chemical propulsion. We see a need for continuing technology base activity for extending life and improving performance of reusable engines. Our activity includes research to enable the design of advanced component hardware, such as the turbopump rotor shown here. In addition, improvements in bearings, seals, and materials will allow for greater durability.

We will continue efforts to model internal dynamic behavior and material response of engine components. Our proposal would develop analytical methods, would do research on engine diagnostic instrumentation, and perform rig testing, all of which would lead to test bed engines to verify physical environments, analytical models, and advanced component behavior. As a result of that, we would begin a test-bed engine program.

The second major thrust, Mr. Chairman, deals with spacecraft (Fig. 8). Power and propulsion subsystems represent about half the weight of a spacecraft. It appears that technology improvements in these areas offer the opportunity for a considerable payload increase. The key elements in the power program are advanced battery research and lightweight solar arrays. Our research in lithium batteries shows the potential for a factor of 5 increase in energy density, and we would continue research on lightweight silicon solar cells, which offer a tenfold increase in power density.

With respect to propulsion, research in xenon ion electric systems points toward the possibility of a major reduction in subsystem mass. In fiscal year 1985, we want to complete performance definition studies.

With respect to communication (Fig. 9), the research program will increase the capacity, versatility, and lower the weight and power consumption of future space communication systems. An initial design at Lewis Research Center for advanced linear traveling wave tubes has shown an increase of 30 percent in power output and more than 100 percent increase in linear range. This linearity permits multiple use of a single channel without intermodulation or cross-talk and has the potential applicability to many space and airborne microwave power transmitters. We would continue the amplifier research in 1985.

Microwave monolithic integrated antenna research has shown that spot beams can be formed and steered electronically permitting versatile use of frequency channels. The antenna amplifier integrated circuits exceed power output specifications presently, and a system comprised of transmitter, receiver, and antenna modules is currently under development.

Finally, with respect to laser research, we would carry out research on solid state lasers for intersatellite links because they have already demonstrated 75 milliwatts of continuous power from a phased array. Our goal in this respect is to achieve 2 watts of power in order to obtain a 1-gigabit-per-second data rate. That is like transmitting the Britannica every second.

Also with respect to spacecraft (fig. 10), autonomous operation will allow for greatly reduced ground operations personnel and systems as well over spacecraft mission life. The objective of the re-

search is to develop and demonstrate space qualifiable computing technology. We want to develop knowledge-based algorithms and data base management systems for artificial intelligence. We have already successfully demonstrated automated planning and scheduling, which Voyager project will test in fiscal year 1985, and activity is continuing for application of this automated planning and scheduling method on the space station and in infrared astronomy missions. Finally, we are developing fault-tolerant software systems, prototype modular components of which have been designed and are being fabricated for integration tests in fiscal year 1985.

With respect to future high-power space missions (fig. 11), which are enabled by the space transportation system, they will require technology to increase the performance and lifetime of energy sources, storage, and management subsystems. Regenerative hydrogen/oxygen fuel cells have promise for significant increase in energy density, while being able to achieve 50,000 discharge cycles needed for low-earth orbit. We would demonstrate a 10-year fuel cell lifetime in low-Earth orbit during 1985.

We are carrying out nuclear power systems activity jointly with the Department of Energy and the Department of Defense. In 1985, we plan to select a nuclear power system approach for ground engineering work. You have heard something about a gallium arsenide concentrator. We are presently directed at cost-effective uses of such devices for power generation. We want to verify a 22 percent efficient concentrator cell in fiscal year 1985.

Research on thermal control systems (fig. 12) is very important to us. We have talked about the use of electric power on Space Station and other craft, but electric power has, as a by-product, heat which must be disposed of. Two phased thermal control systems can provide high-capacity high-precision thermal management at low power and high reliability. We want to continue research in basic physical properties of fluids in low gravity. That is, we want to complete the design of experiments to evaluate flowing two-phase heat transfer, which is to say a mixture of gas and liquid, in space and to analyze the effects of surface tension on two-phase fluids.

We need to evaluate components for heat pipe systems which acquire heat through cold plates, transfer it through heat pipes, store it through phase change, and reject it through radiators. In 1985, a 15-meter long heat-pipe radiator could be ground tested. Initial test of two-phase radiator systems verifying concepts was conducted on STS–8. Also during 1985, we want to test a capillary pump in space.

It is a fact that increased utilization of space is resulting in a factor of 10 increase data output every five years (fig. 13). That is about 50 percent growth per year. Efficient management of information could be accommodated by new network concepts, using distributed information processing nodes, adaptive architecture to accommodate dynamic changes in the operational environment, and software protocols for responsive system reconfiguration. Advanced nodal processors will be a critical technology for adaptive data management networks, which will be realized through optical switching for high-reliability data bus throughput and for fault-tolerant adaptive processors that I have mentioned.

In 1985, we look to identifying and defining promising network architectures, to developing software protocols, and to setting up and conducting systems simulation trade-offs.

Large lightweight deployable structures are required to enable large antenna and reflector systems for future scientific and communications missions (fig. 14). Research is being conducted to continue the development of modeling and analysis activity, and we are working also on active shape control technology. The ground program uses full-sized hardware, a segment of which is shown in the chart, and scale models to obtain data for analytical tools development and comparison will be done. Planning is underway to extend testing and to establish flight technology readiness in the space environment using the shuttle.

Mr. Chairman and members of the subcommittee, this completes my presentation of NASA's planned 1985 space research and technology program. As I said at the beginning, our goal is to continue to provide the necessary technology to maintain preeminence in space. I appreciate this opportunity of presenting what we would like to do and solicit your continued support and advice.

[The prepared statement, plus answers to questions asked of Dr. Martin follow:]

STATEMENT
OF
Dr. John J. Martin
Associate Administrator for
Aeronautics and Space Technology

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

Although this is my first meeting with you as Associate Administrator for Aeronautics and Space Technology, I have had a serious interest in NASA's research activity for many years. During my term as Assistant Secretary of the Air Force for Research, Development, and Logistics, I became very aware of the importance of the NASA programs and the resulting technology contributions. As I am well acquainted with the government process, I know that the support and guidance of this Subcommittee has been and is vital to the success of these activities. I am pleased to be here to summarize our budget request and to describe the NASA Space Research and Technology (R&T) Program planned for FY 1985.

The major emphasis in the FY 1985 Space R&T program continues to be on the disciplinary activities which are listed on the lower half of Figure 1. The program is very generic in nature with long-term continuity focused on the needs of transportation, spacecraft, and platform systems of the future. Where feasible, the technology requirements of advanced systems are identified by analytically assessing the impact of new technology on system performance. These technology needs are balanced with opportunities for quantum improvements in technology over longer periods of time. Our overall goal is to contribute substantially to maintaining the preeminence of the United States in its space endeavors by providing advanced technological options for future systems. We feel strongly that the OAST research of the last decade has contributed significantly to the technological options available to the Space Station initiative announced by the President in his State of the Union message.

Figure 2 contains a summary of the FY 1985 budget request compared with previous years' budgets. A major part of the budget is expended in the R&T Base, which is characterized by generic research with long-term, high-risk, high-payoff technology as its primary objective. The modest increase in the Systems Technology programs reflects increasing attention to chemical propulsion systems technology. The budget also includes $4.9 million to continue support of the Standards and Practices activity managed by the NASA Chief Engineer's Office. Shown also in Figure 2 is the participation in the research program by the NASA civil service staff. Our research staff is an important resource in the program, and would grow modestly in FY 1985.

Allocation of the budget to the discipline and subsystem elements of the program is shown in Figure 3. The systems research portion of the program supports in-space flight research experiments, tests of advanced LOX/hydrogen propulsion system components, multi-disciplinary research focused on transportation, spacecraft, and platform systems, the Orbiter Experiments program, and systems studies to define the technology needs of the future.

Figure 4 shows the distribution of the budget among NASA Centers. The Research Centers (Ames, Langley, and Lewis) account for 54 percent of the budget and the Space Flight Centers receive most of the remainder. The Research Centers have well recognized centers of excellence in disciplinary research. The Space Flight Centers provide selected research expertise and facilitate transition from laboratory research to system applications.

I propose now to discuss significant highlights of the planned FY 1985 program.

Highlights of the research program to provide technology options for future space-based orbit transfer vehicles are illustrated in Figure 5. Systems studies indicate that there are three key technologies: aerobraking, propulsion, and propellant management. In aerobraking research, we plan to continue wind tunnel evaluations of new configurations to characterize their aerodynamic and aeroheating performance parameters. The propulsion program is concerned with engine thermodynamic cycle efficiency, with efficient thermal management within the engine, and with health status instrumentation to diagnose the reuse capability of the engine in space-based applications. In propellant management, a major concern is the ability to transfer cryogenic fluids in space, a necessity for refueling an orbit transfer vehicle. The emphasis of this research is to provide the enabling technology for a reusable and highly-efficient orbit transfer vehicle.

Figure 6 illustrates some highlights of our planned research for highly maneuverable entry vehicles. In the case of the orbit transfer vehicle, the requirement is for a very low lift-to-drag ratio device for aerobraking. For maneuvering entry, the requirement is for a very high lift-to-drag ratio vehicle. At the upper left is shown wind tunnel testing of a configuration in a high Mach number facility. During FY 1985, a number of configurations would be tested to evaluate vehicle performance and thermal protection system (TPS) requirements. In the lower left is shown a structural concept which integrates the propellant tank wall and the primary structure with an attached TPS aeroshell. The purpose of the integrated structural system is to reduce the vehicle weight, thereby increasing payload-carrying capability. We plan also to define the potential use of an entry research vehicle to assess vehicle performance under conditions that cannot be simulated in ground-based wind tunnels or obtained from Shuttle flight data. Although entry data are currently being obtained in our Orbiter Experiments program, the operating design envelope of the highly maneuverable vehicle exceeds that of the Shuttle.

The key thrust of our chemical propulsion research, as shown in Figure 7, is to provide the technology base for improving the life and reliability of reusable engines and for increasing efficiency. The program concentrates on developing methods to predict internal flow and materials response within the complex flow passages of a LOX/hydrogen engine using the Space Shuttle Main Engine (SSME) as a model. During FY 1985, rig tests of advanced, long life components will be initiated based on recent advances in life prediction. Research will continue also in the development of diagnostic instrumentation capable of operating effectively within the hot regions of the engine. Plans call for the initiation of the development of test-bed engine components using existing SSME hardware to expand the researchers' ability to validate the performance of new analytical models and advanced component hardware.

Figure 8 displays the research emphasis in FY 1985 on spacecraft propulsion and power subsystems. As indicated in the center of the chart, about 50 percent of the weight of typical spacecraft is utilized for these two systems. Our objective is to provide technology to reduce significantly the weight of these two systems and thereby increase payload mass. In electric power, current research will continue on advanced lithium battery storage systems which are approximately five times more effective than the current state-of-the-art nickel hydrogen batteries. Research will continue also on lightweight silicon cells which show promise of achieving greater than ten times the power output per unit mass than current flight systems.

As shown in the figure, use of a xenon electric propulsion system has potential for reducing weight by a factor of about three. Recent research has demonstrated some novel concepts to contain the plasma which is generated by the electric propulsion device, thus improving its performance.

Figure 9 shows the thrusts to increase the capacity and versatility of space communications systems while achieving lower weight and lower power requirements. To increase channel capacity, research on traveling wave tube amplifiers will be continued to exploit recent significant developments for achieving higher efficiency and greater linearity of response. Antenna research includes development of an electronically steerable spot beam antenna concept which utilizes monolithic microwave integrated circuits. This concept increases capacity and versatility by permitting simultaneous transmission over the same frequency channel to separate ground receivers. Solid state lasers are being evaluated for intersatellite optical communication links to provide very high data rates (one gigabit per second) with very low weight and electrical power requirements.

As shown in the lower left portion of Figure 10, current spacecraft systems typically require a large complement of ground operations personnel over the entire mission life. Planetary missions can be manpower intensive over periods approaching or even exceeding a decade. Research on system autonomy as a means of greatly reducing operational costs is concentrated in two areas: (1) software and algorithms for knowledge-based systems and data base management to deal with the large amounts of quantified knowledge required; and (2) flight hardware and computing architectures, particularly large-scale, radiation-hardened integrated circuits and fault tolerant computer systems for the data processors. Our research goals are to attain a significant increase in decision making onboard the spacecraft, requiring few, if any, ground operational support personnel.

Increasing user requirements for energy intensive activities in space continue to be forecast and will require increased capacity in future power systems. Some of our research in high-capacity power systems is illustrated in Figure 11. The hydrogen oxygen regenerative fuel cell has promise of significant increases in energy density while being able to achieve the fifty thousand discharge cycles which are needed for low Earth orbit operations. Research on solar cell systems will continue to stress concentrator array technology to permit the cost effective use of expensive gallium arsenide materials for power generation. Nuclear reactor power systems research, being performed in cooperation with the Department of Energy and the Department of Defense, is aimed at defining missions and systems, as well as providing critical technologies for

future space applications. This tri-agency effort is focused on laying the groundwork necessary for making an informed decision as to the future course toward a national capability in this area.

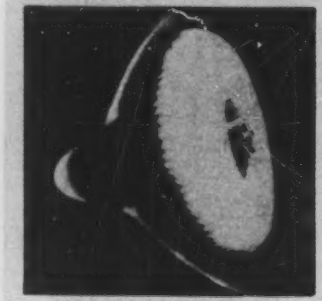
A byproduct of increased electrical power is heat. One of the promising new technologies for thermal control in space is the two-phase system which uses both liquid and gas as the energy transport media. As shown in Figure 12, the research program consists of three major thrusts: (1) improved understanding of the basic heat transfer and surface tension behavior of two-phase materials in low gravity; (2) establishing the critical technology for two-phase components, such as the heat pipe radiator shown in the center of the figure; and (3) in-space testing of key system elements, such as the radiator, when their performance cannot be simulated in a ground laboratory. On the top right is a photograph of the initial test of a two-phase radiator system conducted on STS-8. We forecast a future scale-up of the in-space experiment leading to system verification of the two-phase thermal control concept.

Increased utilization of space is resulting in a factor-of-ten increase in acquired data from sophisticated spacecraft every five years. One element of our data systems research concentrates on adaptive networks to control the flow of data within a large platform. As shown in Figure 13, the essence of this research is in dealing with a distributed information system allowing local access to the the system at points where the data are either generated or processed. The data system must have an architecture which can adapt itself to dynamic changes in operational data demands and to the geometry of the platform and related spacecraft. Precedence rules for software execution are required to provide responsiveness to the system configuration at the nodes. Research is continuing on optical switching to yield high reliability and high through-put and on fault tolerant, adaptive local nodal processors.

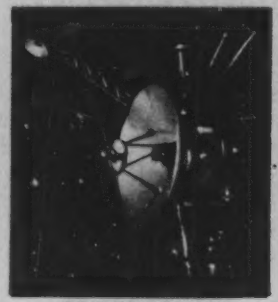
Research will continue on very large antenna and reflector structures for use in both scientific and communication systems. The objective is to produce very lightweight deployable structures with active surface shape control. Control is required to obtain desired beam characteristics by maintaining the contour of the antenna or reflector during flight variations in load and temperature. Shown in the background of Figure 14 is a section of a 50-meter deployable antenna concept installed in a ground test apparatus intended to simulate zero-g loading. The objective is to provide ground and flight test data to verify static, dynamic, and thermal predictive analysis methods for such structures.

The examples I have discussed represent some highlights of our planned FY 1985 Space Research and Technology program. Our continuing goal is to provide technology responsive to the Nation's needs in maintaining preeminence of the U.S. presence in space. Thank you for this opportunity to summarize our proposed program. I solicit your support.

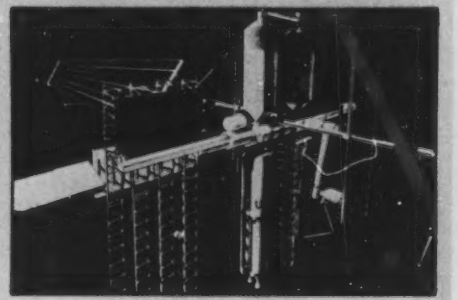
MAINTAIN UNITED STATES PREEMINENCE IN SPACE



TRANSPORTATION



SPACECRAFT



PLATFORMS

RESEARCH & TECHNOLOGY FOR NATIONAL SPACE MISSIONS

- MATERIALS AND STRUCTURES
- ENERGY CONVERSION
- COMPUTER SCIENCE AND ELECTRONICS
- PROPULSION
- CONTROLS AND HUMAN FACTORS
- FLUID AND THERMAL PHYSICS
- DATA AND COMMUNICATIONS

NASA

OAST NASA HQ RS83-783(3) Rev. 8-3-83

Figure 1

SPACE RESEARCH AND TECHNOLOGY

	R&D BUDGET ($,M)			
		FY 1984		FY 1985
	FY 1983	BUDGET ESTIMATE	CURRENT ESTIMATE	BUDGET ESTIMATE
RESEARCH & TECHNOLOGY BASE	116.3	126.2	125.4	136.0
SYSTEMS TECHNOLOGY PROGRAMS	5.2	7.2	7.0	9.1
SUBTOTAL SPACE R&T	121.5	133.4	132.4	145.1
STANDARDS & PRACTICES	3.0	4.6	4.6	4.9
TOTAL	124.5	138.0	137.0	150.0
	EQUIVALENT WORK YEARS			
DIRECT CIVIL SERVICE	1,340	1,400	1,408	1,422

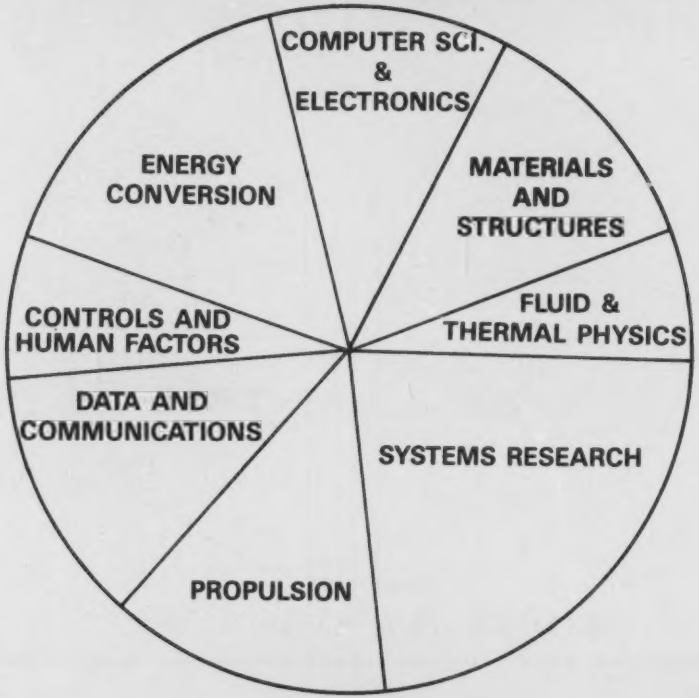
NASA

Figure 2

OAST NASA HQ RS84-704 (1)
1-12-84

SPACE RESEARCH AND TECHNOLOGY

DISTRIBUTION BY TECHNICAL AREA



NASA

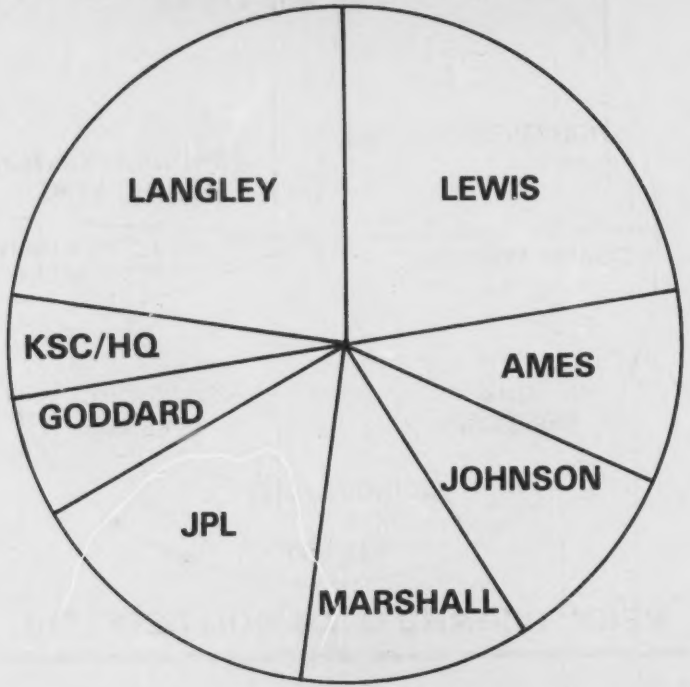
$145.1M

OAST NASA HQ RS84-703 (1) 1-12-84

Figure 3

SPACE RESEARCH AND TECHNOLOGY

DISTRIBUTION BY CENTER



$145.1M

NASA

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1-12-84

Figure 4

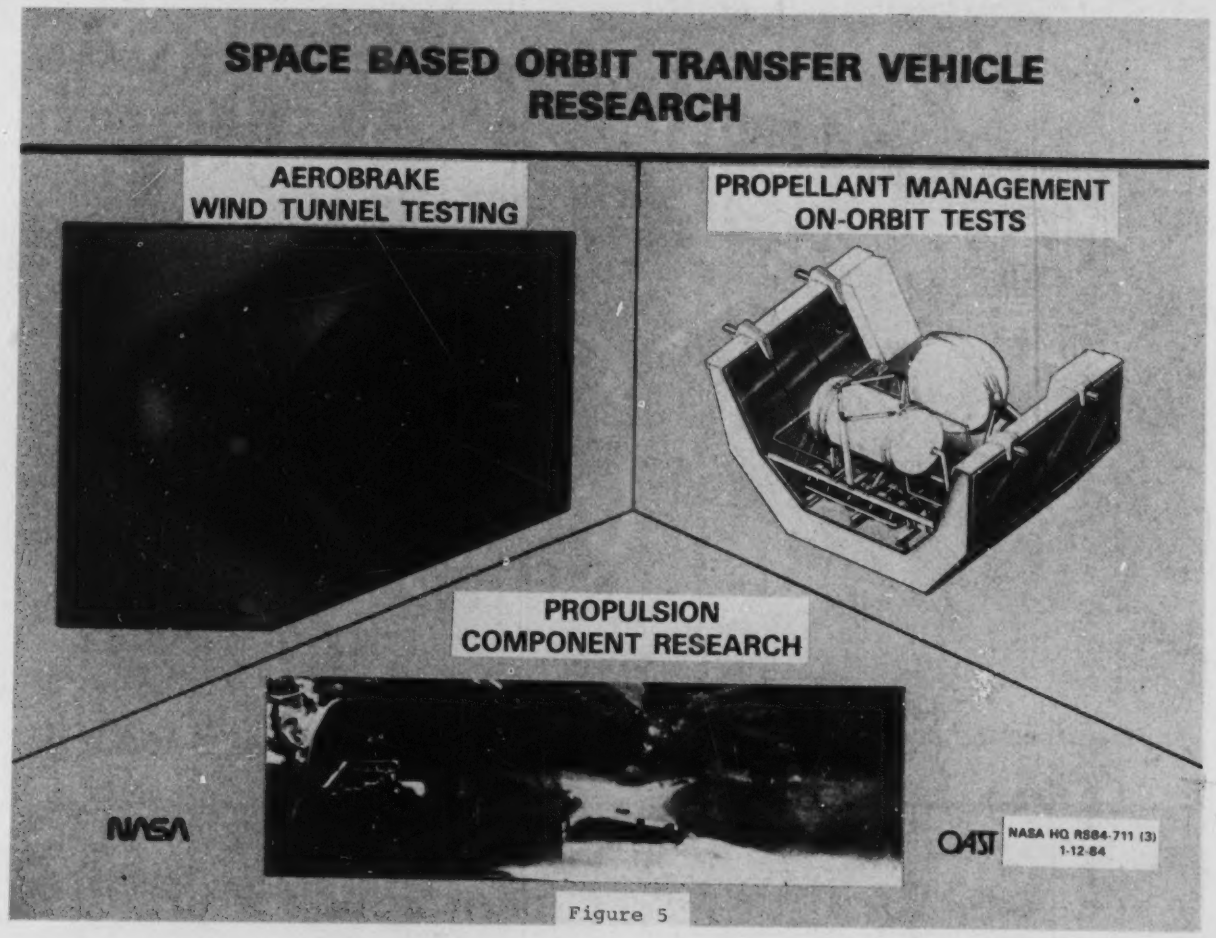
SPACE BASED ORBIT TRANSFER VEHICLE RESEARCH
AEROBRAKE WIND TUNNEL TESTING
PROPELLANT MANAGEMENT ON-ORBIT TESTS
PROPULSION COMPONENT RESEARCH
NASA
OAST
NASA HQ RS84-711 (3)
1-12-84

Figure 5

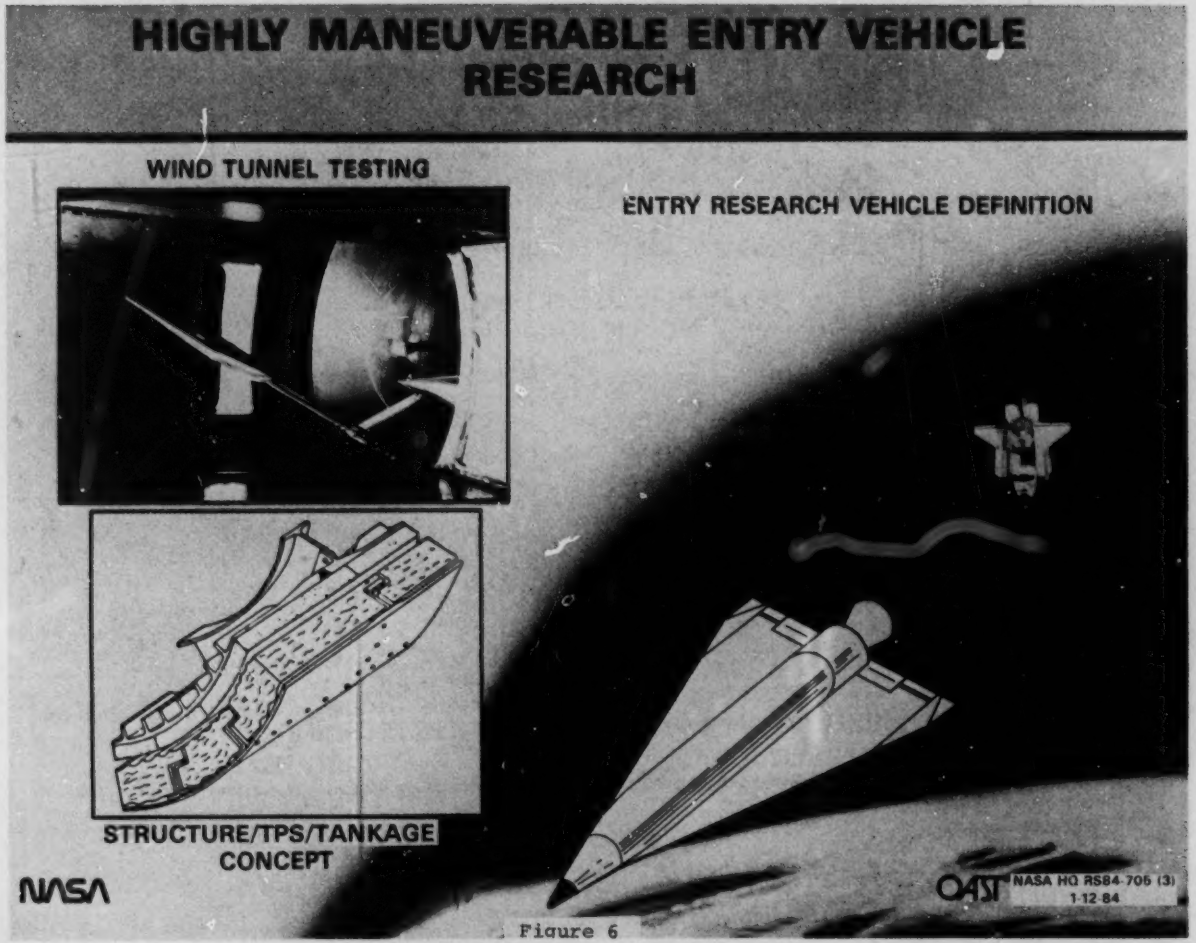
HIGHLY MANEUVERABLE ENTRY VEHICLE RESEARCH
WIND TUNNEL TESTING
ENTRY RESEARCH VEHICLE DEFINITION
STRUCTURE/TPS/TANKAGE CONCEPT
NASA
OAST
NASA HQ RS84-705 (3)
1-12-84

Figure 6

RESEARCH IN LOX/HYDROGEN CHEMICAL PROPULSION

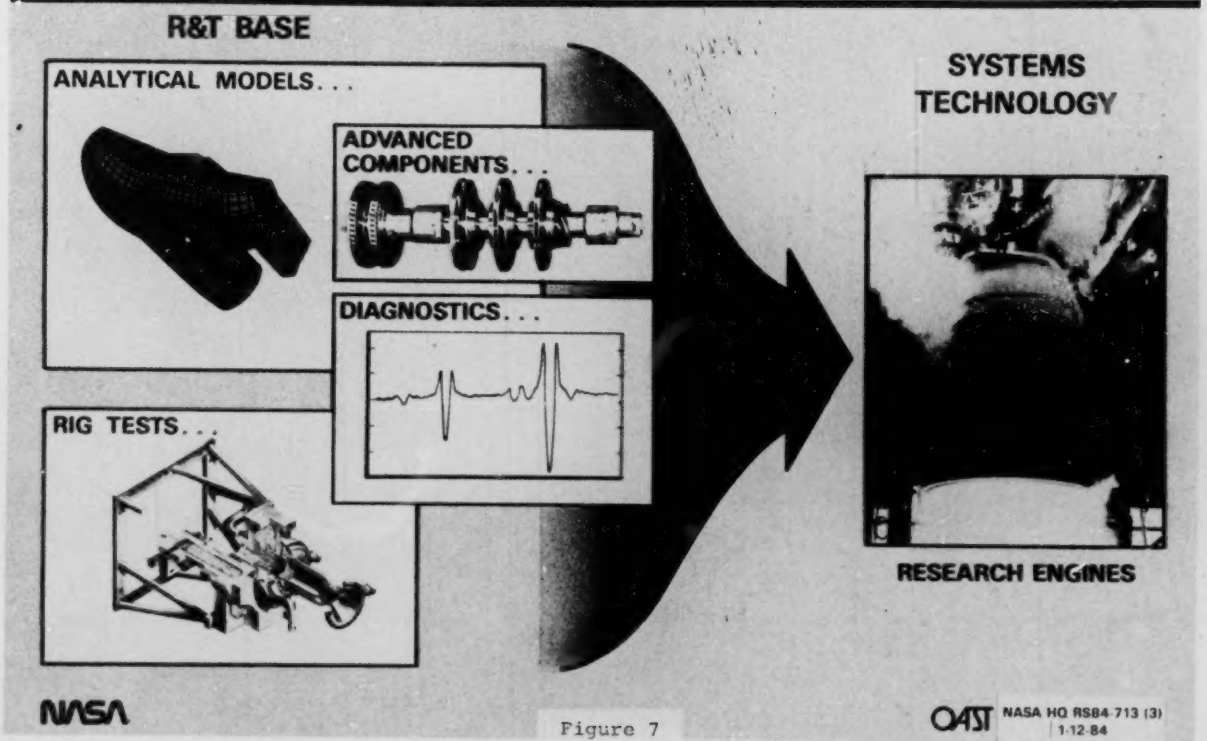

Figure 7

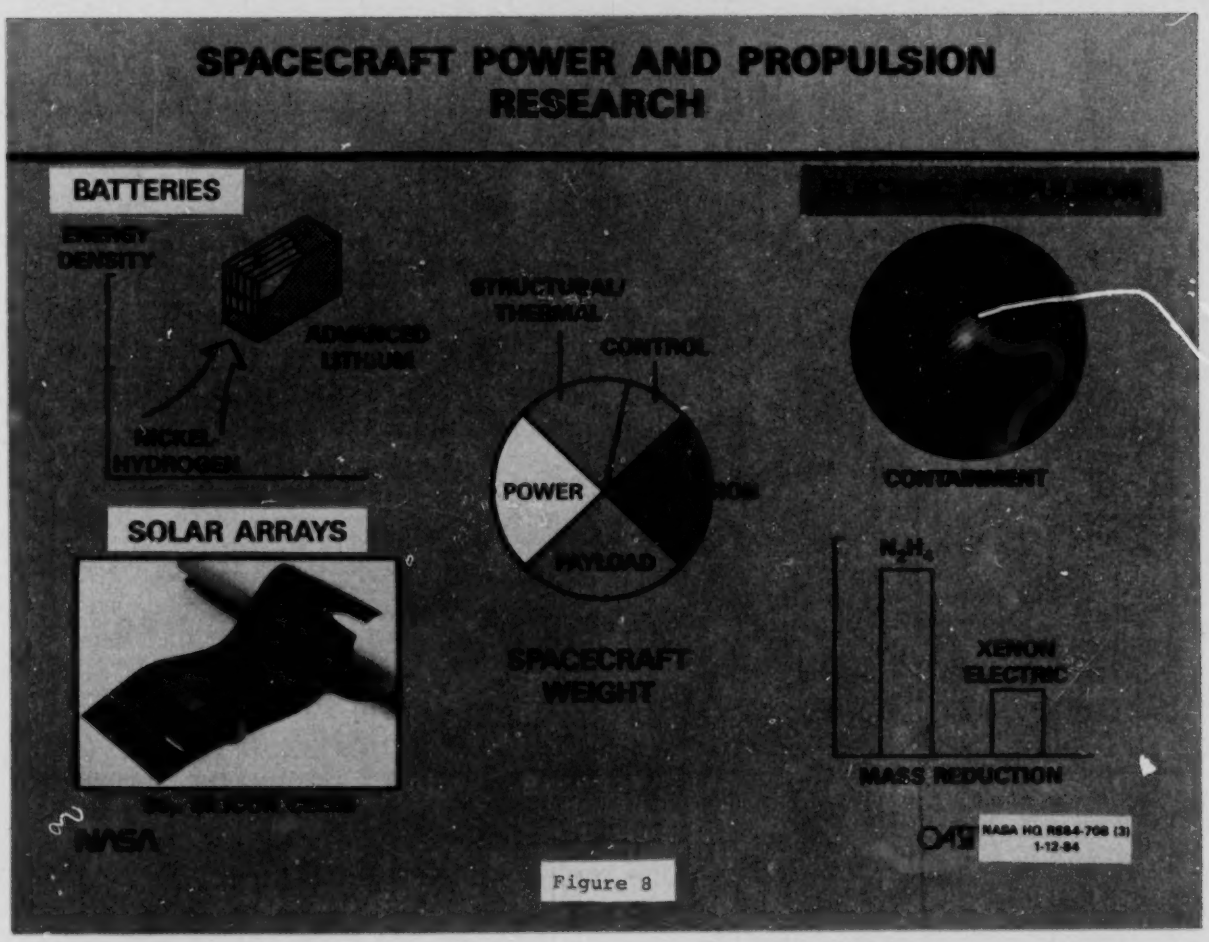
SPACECRAFT POWER AND PROPULSION RESEARCH
BATTERIES
ENERGY DENSITY
ADVANCED LITHIUM
NICKEL HYDROGEN
SOLAR ARRAYS
STRUCTURAL/ THERMAL
CONTROL
POWER
PAYLOAD
SPACECRAFT WEIGHT
CONTAINMENT
N_2H_4
XENON ELECTRIC
MASS REDUCTION
NASA HQ R884-708 (3) 1-12-84

Figure 8

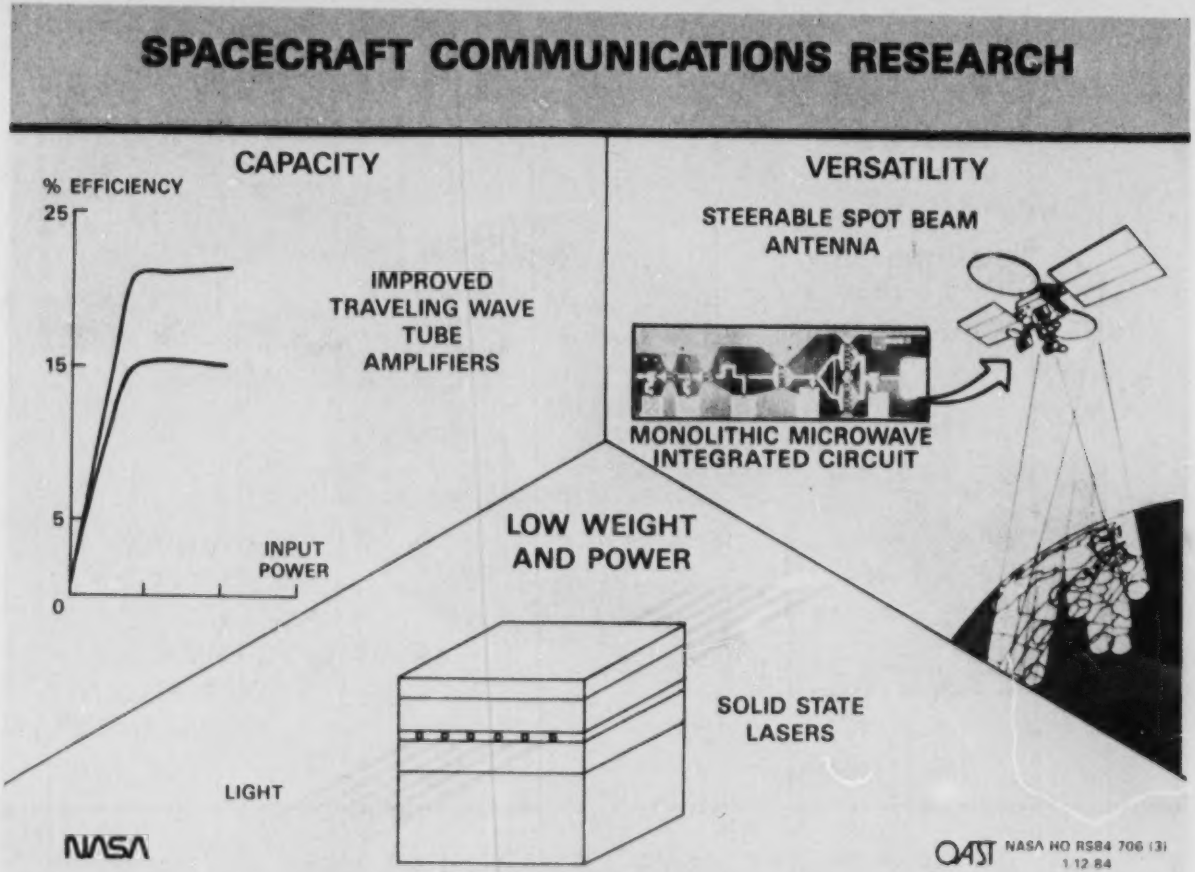
SPACECRAFT COMMUNICATIONS RESEARCH
CAPACITY
% EFFICIENCY
25
15
5
0
INPUT POWER
IMPROVED TRAVELING WAVE TUBE AMPLIFIERS
VERSATILITY
STEERABLE SPOT BEAM ANTENNA
MONOLITHIC MICROWAVE INTEGRATED CIRCUIT
LOW WEIGHT AND POWER
SOLID STATE LASERS
LIGHT
NASA
OAST
NASA HQ RS84 706 (3)
1.12.84

Figure 9

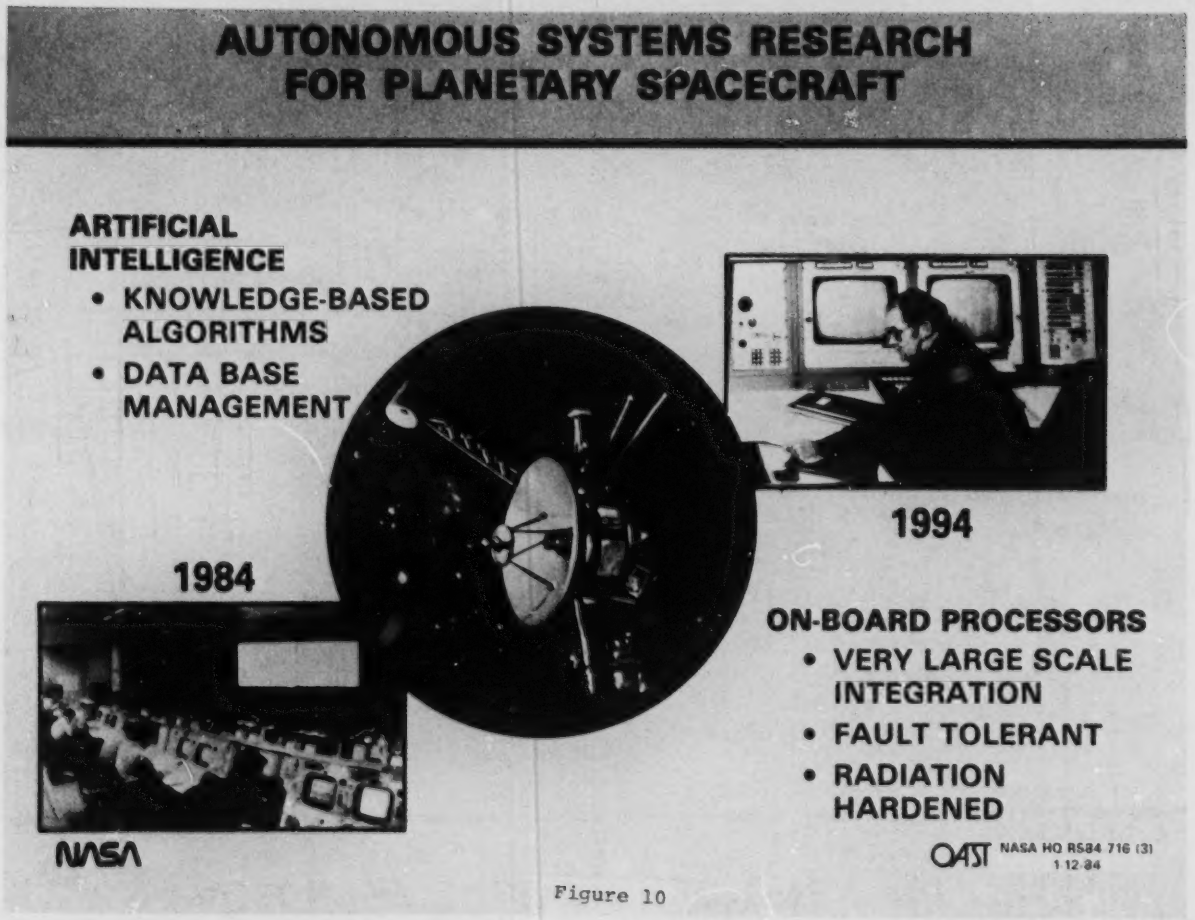
AUTONOMOUS SYSTEMS RESEARCH
FOR PLANETARY SPACECRAFT
ARTIFICIAL
INTELLIGENCE
• KNOWLEDGE-BASED ALGORITHMS
• DATA BASE MANAGEMENT
1994
1984
ON-BOARD PROCESSORS
• VERY LARGE SCALE INTEGRATION
• FAULT TOLERANT
• RADIATION HARDENED
NASA
OAST
NASA HQ RS84 716 (3)
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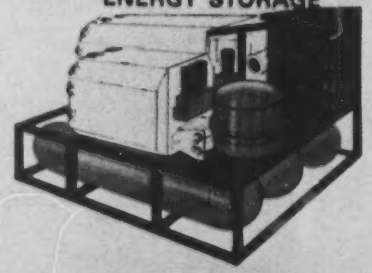
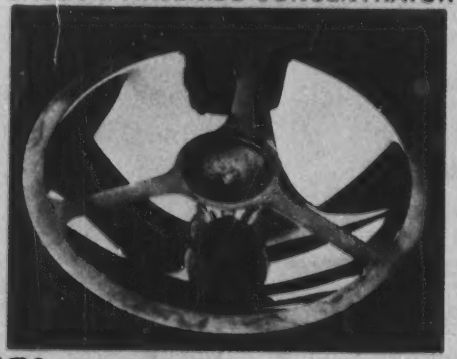
Figure 10

RESEARCH ON HIGH CAPACITY POWER SYSTEMS

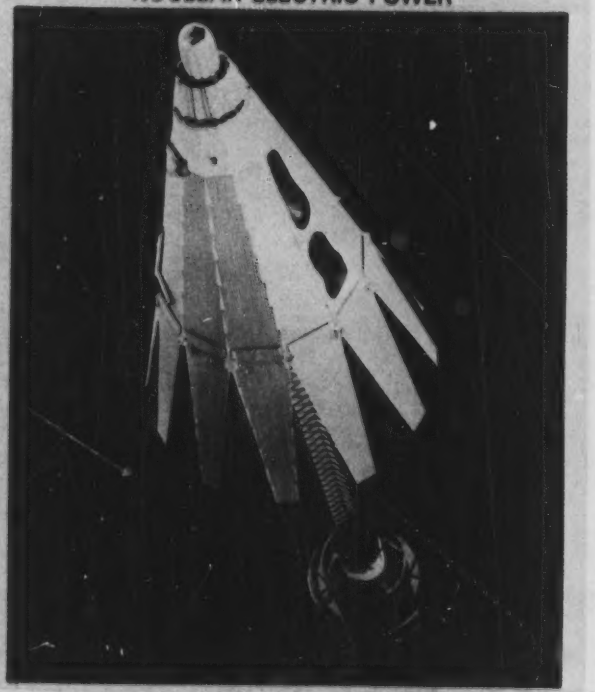
REGENERATIVE FUEL CELL ENERGY STORAGE



GALLIUM ARSENIDE CONCENTRATOR



NUCLEAR ELECTRIC POWER



NASA

Figure 11

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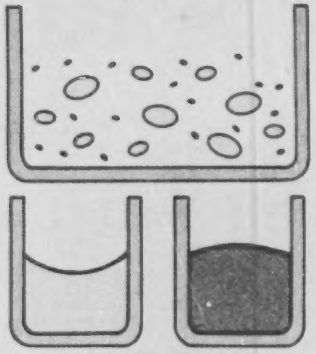
84-282 O—84—14

RESEARCH ON TWO PHASE THERMAL CONTROL SYSTEMS

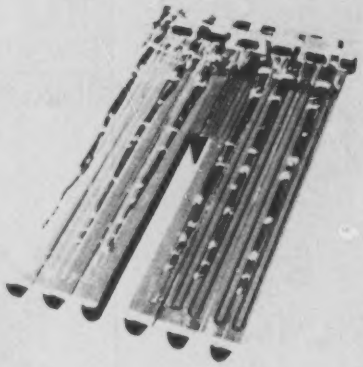
BASIC PROPERTIES

HEAT TRANSFER



SURFACE TENSION PHENOMENA

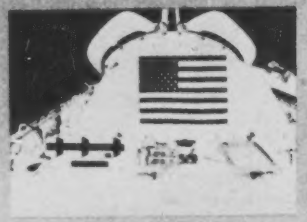
COMPONENTS

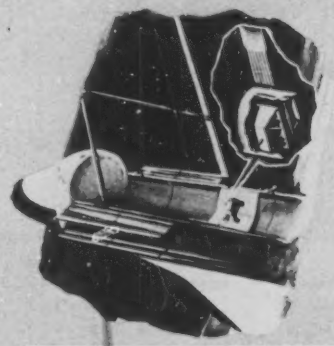


HIGH-CAPACITY HEAT PIPE TESTS

IN-SPACE EXPERIMENTS

STS-8 HEAT PIPE TEST





RADIATOR VERIFICATION

NASA

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Figure 12

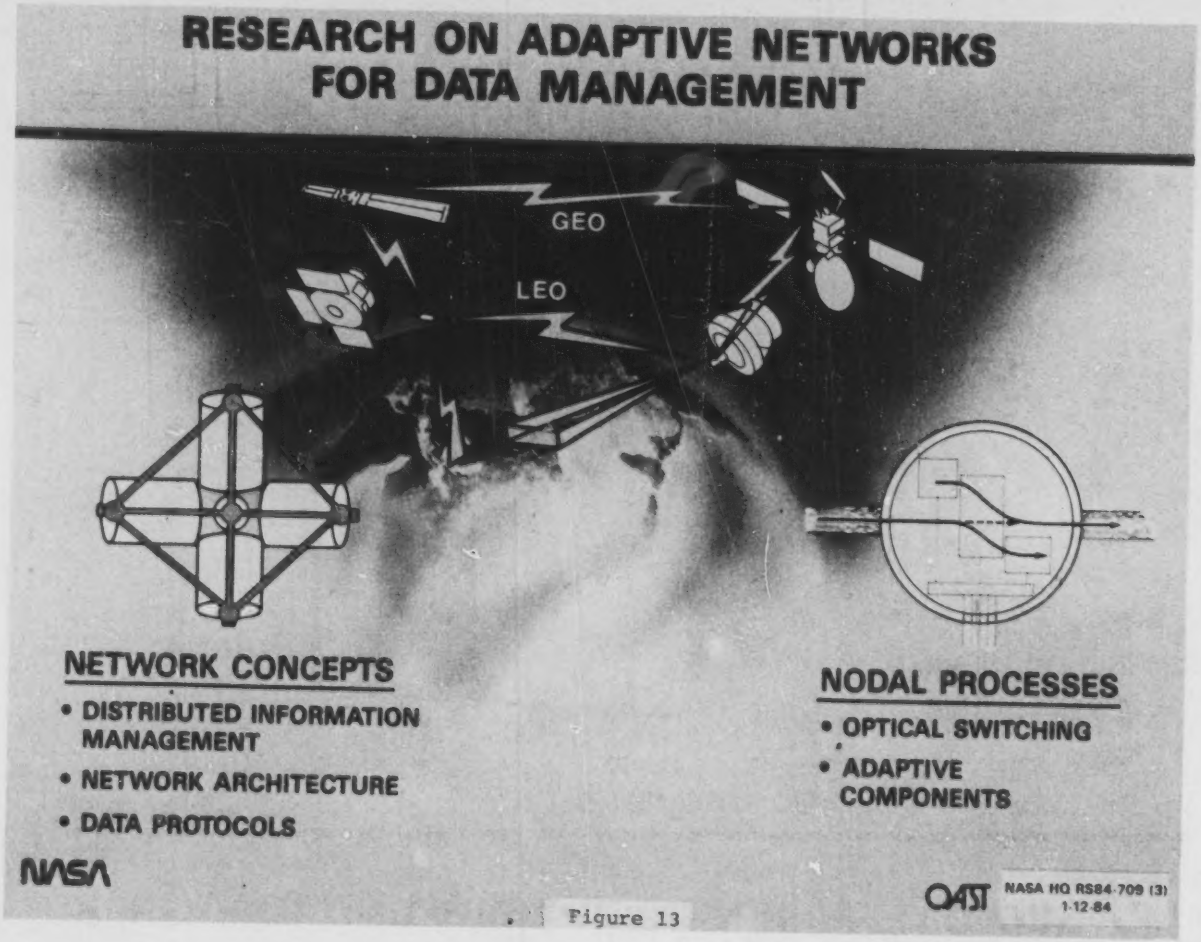

RESEARCH ON ADAPTIVE NETWORKS
FOR DATA MANAGEMENT
GEO
LEO
NETWORK CONCEPTS
• DISTRIBUTED INFORMATION MANAGEMENT
• NETWORK ARCHITECTURE
• DATA PROTOCOLS
NODAL PROCESSES
• OPTICAL SWITCHING
• ADAPTIVE COMPONENTS
NASA
OAST
NASA HQ RS84-709 (3)
1-12-84

Figure 13

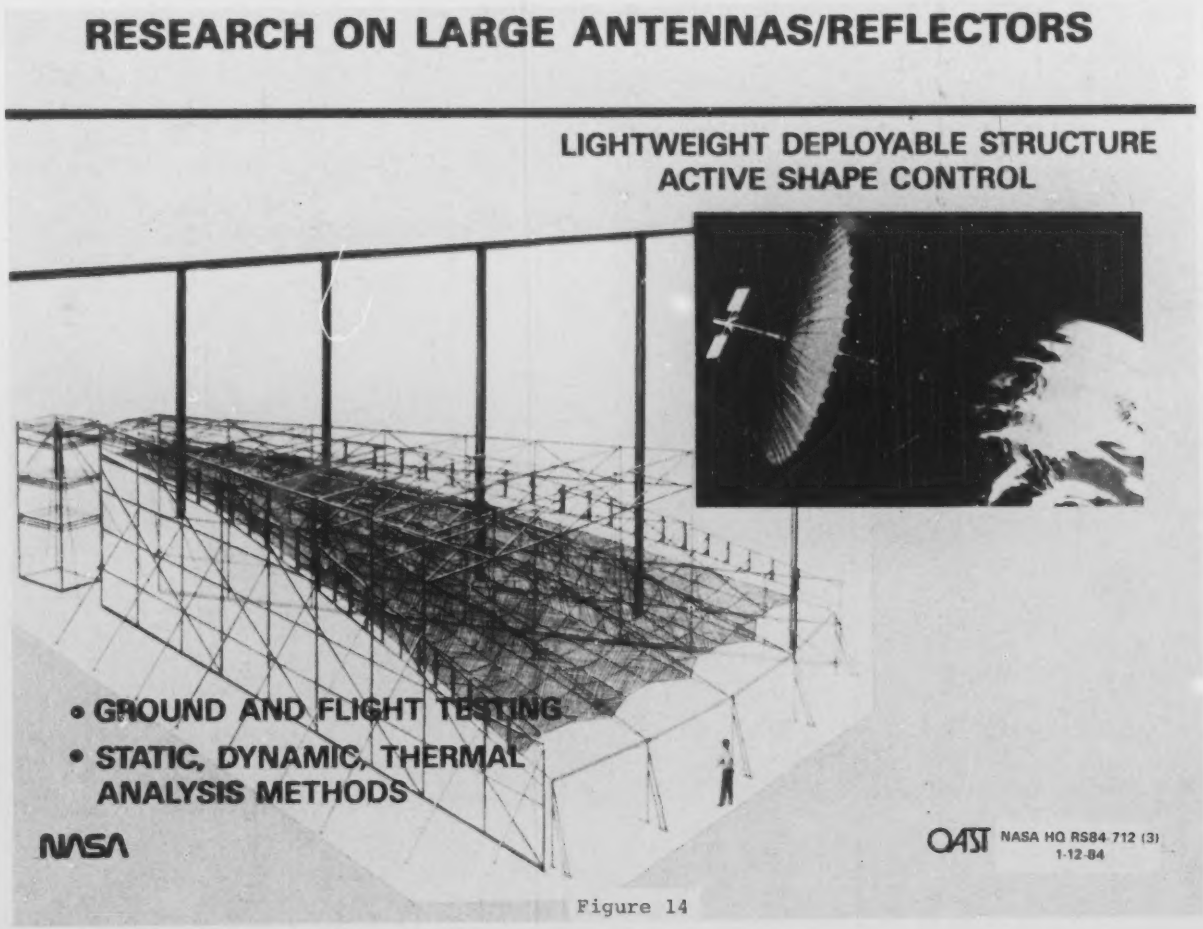

RESEARCH ON LARGE ANTENNAS/REFLECTORS
LIGHTWEIGHT DEPLOYABLE STRUCTURE
ACTIVE SHAPE CONTROL
• GROUND AND FLIGHT TESTING
• STATIC, DYNAMIC, THERMAL ANALYSIS METHODS
NASA
OAST
NASA HQ RS84-712 (3)
1-12-84

Figure 14

RESPONSES TO WRITTEN QUESTIONS RESULTING FROM THE FEBRUARY 2, 1984, HEARING BEFORE THE HOUSE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS AT WHICH DR. MARTIN TESTIFIED.

QUESTION R-1:

Since the early 1960's, NASA's funding of Space Research and Technology has declined from 5 percent of the NASA budget to below 2 percent of the NASA budget. Given that this activity provides the technology base for all of NASA's future programs, do you really believe that it is being adequately funded?

If not, what will be done to correct this situation?

ANSWER R-1:

Over the past three years, there has been an increase in Space R&T funding relative to NASA's total budget. Our FY 1985 funding request is 9 percent above FY 1984, over twice the increase in the NASA budget as a whole. Thus, we believe the Space R&T program receives an adequate portion of the total Agency budget.

Within the current framework, we are reviewing our involvement in the development of advanced technologies for space. If warranted, adjustments in the allocation of funding will be made to assure optimum use of NASA's unique talents and facilities to support and complement the expanding space efforts.

QUESTION R-2:

Last October, 50 percent of the senior management slots in your Space Systems and Aerospace Research Divisions were occupied by "acting" personnel. Why was this management situation allowed to degenerate to such an extent?

What is being done to correct it?

ANSWER R-2:

There is a total of twelve Senior Executive Service (SES) positions in the Aerospace Research Division and the Space Systems Division. In July 1983, four (or 33 percent) of these positions were filled by acting incumbents. Two of these four positions had been advertised and we were in the early stages of the recruiting process for the third when the Associate Administrator of OAST left to return to the Massachusetts Institute of Technology. At that time, all OAST senior executive staffing activities were suspended pending selection of a permanent replacement for the Associate Administrator.

Dr. John Martin was named Associate Administrator of OAST in January 1984. He is currently reviewing and evaluating the present OAST organization and will be filling positions in the near future. We will keep the Subcommittee informed of our progress in this important matter.

QUESTION R-3:

Roughly 1/3 of your research efforts are in support of DOD needs. Do you think that this is a healthy situation or does it not divert funds from civil research needs?

Do you foresee any trend to increase your level of support for DOD programs?

ANSWER R-3:

The NASA Space R&T program is not directed to explicit support of DOD requirements. However, we estimate that about 80 percent of the OAST program is of significant benefit to DOD needs. Much of the NASA program is of a long-range, generic nature and is oriented towards research opportunities that are common to both civil and military future missions. Furthermore, many of the requirements for civil missions are quite similar to military needs, such as technology for large space systems, radiation-hardened electronics, and spacecraft autonomy. We foresee no change in this percentage of synergistic research.

QUESTION R-4:

Last summer, the National Research Council published a report on NASA's Space Research and Technology Program. In this report, the Council made a number of institutional and technical recommendations.

a. What is NASA's position on those recommendations?

b. What is being done to implement them?

c. Which specific recommendations do you disagree with?

ANSWER R-4:

We are in the process of evaluating the recommendations made by the National Research Council in its report entitled "NASA's Space Research and Technology Program." NASA recognizes that we have unique talents and capabilities that could support the country's national space requirements which include our own as well as other civil, commercial and DOD needs. OAST is exploring how NASA might provide such support. Specifically, Dr. Donald Hearth, Director of the Langley Research Center,

has been meeting with national space leaders from industry and universities, many of whom have had considerable experience in working with NASA in aeronautics, to discuss questions of implementation. We expect to hear his recommendations shortly. A large portion of our R&T base is already applicable to commercial users. Our Research Centers will continue to work with industry to define program needs.

QUESTION R-5:

In its Mission of NASA study last fall, the NASA Advisory Council endorsed the National Research Council's recommendations and suggested that your Space Research and Technology effort be expanded and reorganized to provide the kind of support for the space community that your aeronautics R&D efforts provide for the aeronautics community.

a. What is NASA's position on these recommendations?

b. What is being done to implement them?

ANSWER R-5:

As stated in the response to Question R-4, we are reviewing the recommendations and are continuing as before to work with industry to define programs which would optimize generic R&T Base programs for future spacecraft technology needs.

QUESTION R-6:

Until now, OAST's Space Research and Technology efforts have been conducted principally in support of NASA needs.

a. With the prospect of increased commercial involvement in space, what effect, if any, do you see on your research policy?

b. To what extent do your Space Research and Technology efforts support DOD needs? Is DOD research (e.g., in materials sciences) applicable and easily transferrable to NASA needs?

ANSWER R-6:

The prospect of increased commercial involvement in space suggests the possibility of more intensive pursuit of relevant research and technology efforts as suggested by the National Research Council (Question R-4). It does not call for a policy change in that the existing NASA charter, as defined by the Space Act of 1958, adequately defines this role.

As stated in the response to Question R-3, the Space R&T efforts, without being explicitly directed at DOD support,

provide a significant synergistic benefit to satisfying DOD needs. The OAST Space Research and Technology program is predominantly of a discipline-oriented, fundamental nature, aimed at providing generic technology that is needed for any activities in space, civil or military, government or commercial. As such, it already addresses many of the generic commercial and DOD interests. Similarly, portions of DOD research at the basic levels are applicable and transferable to satisfying NASA needs.

QUESTION R-7:

Recently the State Department has expressed concern over the transfer of space technology to other countries.

a. Do you share their concern?

b. How can we solicit international cooperation in such programs as the Space Station without such transfers?

ANSWER R-7:

NASA shares the concern of the State Department over the transfer of space technology to other countries. That is why NASA has always conducted its international activities so as to minimize unwarranted technology transfer and insure mutual benefit, and we will do so in the Space Station program, as well.

Regarding critical national defense items, NASA believes these items should be restricted or classified. Regarding technologies with important civil/industrial applications, it is important that the developments of our R&D programs be made available as rapidly as possible to U.S. industry, so that we can stay ahead of foreign competition.

In cooperative activities, NASA looks for discrete hardware contributions, and not subsystem contributions. Furthermore, foreign partners are expected to assume full financial and technological responsibility for their portion of the program. NASA provides only that information which is necessary for effective interface.

Similar procedures would be available for the Space Station program. For example, if a foreign partner chose to furnish a module dedicated to experimental manufacturing in space, we would establish a mechanical interface to the Space Station and provide certain housekeeping services.

QUESTION R-8:

Can you please explain the reason for the 87 percent (or $4.5 million) increase in the Spacecraft Systems Research and Technology account?

ANSWER R-8:

The increase in the Spacecraft Systems Research and Technology account is due to the increased support ($3.5 million) for the cryogenic fluid management in-space flight experiments. Understanding of cryogen behavior and their transfer in space will be essential to potential future space-based orbital transfer vehicles. Continuation of ground-based research and in-space flight testing at this time can make highly efficient use of the Shuttle as a test-bed to provide data in a timely way.

QUESTION R-9:

Can you please explain the reason for the 25 percent (or $3.5 million) increase in the Materials and Structures Research and Technology account?

ANSWER R-9:

OAST has been aware for some time of the need for space flight experiments in the structures, structural dynamics and controls programs. Such experiments will provide verification of analytical models for predicting and controlling the performance and stability of large, flexible or segmented, structures in the space environment. The Shuttle Orbiter is a suitable test bed for such experiments. Preparation for experiments must begin now if results are to be available in a timely fashion to support a variety of NASA missions. The funding increase in the Materials and Structures Research and Technology account will provide for the design and the initiation of construction of subscale and full-scale models to develop and evaluate analytical methods and modeling techniques. In addition, preliminary design of systems to integrate experiments with the Shuttle will be initiated. Results from these fundamental studies will provide a basis for planning space flight experiments.

Mr. VOLKMER. Thank you very much, Dr. Martin. Some of these questions may go into particulars whereby you may have to report back to us later on. If they do, just say so, or if you need some help from somebody who has been at it a little longer, just let them answer the question, if you can.

Dr. MARTIN. Thank you.

Mr. VOLKMER. In looking over the budget for the past several years, we notice that the space research and technology in NASA's budget declined one time in the sixties to around 5 percent of the total NASA budget. Now we are down in this 1985 budget to about 2 percent. So that is better than we were a year ago and the year before, because for a while they were down around 1.5 or 1.6 percent. Do you believe that we are adequately funded as far as all the research needs that we need to do, what I call the basic research technology for things we need to get into?

Dr. MARTIN. I will defer to Dr. Colladay in a moment, but I have not been at it long enough to have formed an opinion on that subject. I intend to do that, and if I come to the conclusion, which you have at least hinted at, I certainly would not hesitate to say to Mr. Beggs that I had that feeling. But I am not at that point at this time.

Dr. COLLADAY. I guess, Mr. Chairman, one of the ways that one might answer that is how well we were able to lay the base and the foundation for space station long before we have gotten to the point we are today. We started a number of the technologies because they had particular drivers for what we saw to be our continued presence in space, even beyond what you would think of as manned-presence 5 or 6 years ago in many of these technologies. They did not go far enough to put the technology on the shelf, and I would say that is probably our biggest shortcoming, if there is one, in the size of our investment in advanced technology. We do try and cover the breadth of opportunities that we see coming downstream over a period of 10 to 15 years, and we carry them to a point where we prove initial feasibility but not reach a point of technology readiness.

It is appropriate that a program like the space station that we are trying to embark on further focus those technologies and carry them to that point where we would have the confidence of baselining them into the design. That is exactly what the additional $34 million on top of our generic base program that John Hodge talked about is intended to do. I guess, as technologists, we would all like to see more effort being put into advanced technology and research. There is not a shortage of ideas. But I think on the whole, we are doing the job of looking out with long-term high-risk areas that the Office of Aeronautics and Space Technology should be doing.

Mr. VOLKMER. Of the labs' and centers' money that you have shown on this one here, the $145.1 million, is there any way to determine how much goes from the labs or the centers to university research centers?

Dr. MARTIN. It is not a number which is directly derivable, Mr. Chairman, but we think in those terms. If Dr. Colladay does not have it at the tip of his tongue, we will get it for you.

Mr. VOLKMER. I would like to have that just for information purposes. In other words, how much is retained in the center or the lab ongoing and how much is maybe funneled out to universities.

Dr. COLLADAY. We will provide that for the record, Mr. Chairman, as well as that portion that goes to the industry and cooperative programs with us.

[The information follows:]

Of the $145.1 million FY 1985 Space R&T budget request, it is estimated that approximately 11 percent ($16 million) will go to universities and colleges. Approximately 37 percent ($54 million) is expected to be spent on research contracts with industry. The balance of the $145.1 million will support in-house research efforts including the Space R&T work performed at the Jet Propulsion Laboratory.

Mr. VOLKMER. There is another one you may have to get back to me as to the total programs that we have ongoing now, in the research in the spacecraft and to the batteries and to the nuclear energy, electrical energy for the future—all those. Of the total gamut of the research that is being done in new technology, how much will be what I would call this year a new start and how much is ongoing from what you have been doing in the labs last year, the year before, or the year before that. I do not want to know what has been done before; I would like to know what is the new, where are we starting, and who has come up with a new idea that we need to start on this year.

Dr. MARTIN. "What have you done for me lately?"

Mr. VOLKMER. Right.

Dr. COLLADAY. We would provide that also for the record. I would just add, in terms of the qualitative end of that, in the base research program we feel that we roll over or stop things and start new things on the order of 20 percent of the program each year.

[The information follows:]

There are no new initiatives in the Space R&T Program for FY 1985. We do, however, normally provide for advancing technology frontiers in our on-going program by "roll over" of about 20 percent of the program each year. Following is a list of some of the changes we plan during FY 1985:

Research on technology for large deployable reflector systems at Ames and Langley Research Centers

Initiation of a study of advanced technology requirements for planetary augmented missions at Jet Propulsion Laboratory

Research on high lift-to-drag entry technology at Langley Research Center, including an evaluation of requirements for a flight test vehicle

A two-fold increase in research on analytical modeling of hot gas system flow dynamics, material behavior, and structural response in the LOX/hydrogen research program at Lewis Research Center

Initiation of research on superlattice concepts for power components at Lewis Research Center

Investigate potential of integrating energy storage and momentum control at Langley Research Center

Conduct research on rarefield nonequilibrium gas effects for orbital transfer and transatmospheric vehicles at Langley Research Center.

Explore potential of space processing of nonterrestrial materials for use in space at Jet Propulsion Laboratory.

Develop space experiment to study dynamics of large space structures.

Increased emphasis on artificial intelligence and expert systems technology for planning, scheduling, and maintenance of space missions.

Mr. VOLKMER. Again, this may not be exactly a fair question for you, Mr. Martin, but it is one that if you cannot answer it now, in several months after you have been there a while longer, maybe you can come back and let us know what you have done about the

problem. As I understand, and you can correct me if I am wrong on this, last October about 50 percent of the senior management positions in the space systems and aerospace research division were occupied by acting personnel. If that is true, I would like to know what is going to be done about it. If that is still true, what plans are you making to have permanent positions? I also would like to know what the reasons for it is.

Dr. MARTIN. We solved one of those. I think that part of the delay was due, Mr. Chairman, to the fact that——

Mr. VOLKMER. They were getting you on board.

Dr. MARTIN. In essence, that; but Dr. Colladay was kind enough to leave many of those kinds of decisions to the successor to Dr. Kerrebrock, who was my predecessor. So that in some sense I am the reason that happened. There might be other reasons as well, but I think that might have been the primary one. We have been talking in terms of what to do about it and intend, within the next month or two, to try to take care of those "acting" situations and get a sound full-time organization, so to speak.

Mr. VOLKMER. Some of the research that is being done is being done in conjunction with DOD, but a lot of it affects DOD to their benefit. It will be for their needs. How much of that totally would you say is being done within the total research?

Dr. MARTIN. It is not the goal of our activity to support the Department of Defense directly, as you certainly understand.

Mr. VOLKMER. I agree with that, but indirectly——

Dr. MARTIN. I am going to get to that. But we do think in those terms. When estimates are made that something like 80 percent of what we do has some utility to the Department of Defense.

Mr. VOLKMER. But it also has utility as far as the civil space program?

Dr. MARTIN. That is the sine qua non, Mr. Chairman.

Mr. VOLKMER. We get very little contribution from DOD unless we have something we are specifically working with them on by agreement; is that correct? You get no reimbursement on it from DOD unless it is something by agreement with DOD?

Dr. COLLADAY. That is correct, although through joint planning, as we do with the DOD, we get a lot of leverage out of making sure that our programs are coordinated, but not reimbursable; you are correct.

Dr. MARTIN. If I might interject, Mr. Chairman, nothing that I have said should indicate that we have an arms' length attitude with respect to the Department of Defense. We do not. We have excellent relationships with them and enjoy working with them.

Mr. VOLKMER. Is it fair to assume then that you receive no reimbursement from DOD?

Dr. MARTIN. I cannot answer a flat question like that. I do not have the experience.

Mr. VOLKMER. I would like to know and how much you received in the last fiscal year.

Dr. MARTIN. Yes, sir.

Dr. COLLADAY. We will provide that, but essentially you are correct, I will make sure of that, in the literal sense of reimbursable programs.

[The information follows:]

During fiscal year 1983, the Office of Aeronautics and Space Technology received approximately $7 million in Space R&T reimbursements from the Department of Defense (DOD). In fiscal year 1984, we expect to receive approximately the same amount of reimbursable Space R&T funding from DOD. These funds are primarily related to the Space Nuclear Power Technology (SP-100) program which is carried out via a tri-agency agreement involving NASA, DOD and the Department of Energy.

Mr. VOLKMER. Last summer the National Research Council published a report on NASA's space research and technology program. In this report, I understand the Council made a number of institutional and technical recommendations. Have you been able to evaluate that and make a determination or a position on these recommendations?

Dr. COLLADAY. We are in the process, Mr. Chairman, of evaluating the full impact of the recommendations of that report on our program and the institutional structure of our centers. There are, as you know, a number of sweeping recommendations that, if fully implemented, would have a major impact not only on the way we do business but the very policy of how we conduct the space technology program.

Mr. VOLKMER. Does the dog wag the tail or does the tail wag the dog? Is that what you are trying to say a little bit?

Dr. COLLADAY. I guess you could put it that way. To the extent that those recommendations impact the budget, we are just in the process of going through the evaluation this year.

Mr. VOLKMER. Are there any specific recommendations that you have already decided that you overwhelmingly or violently disagree with?

Dr. COLLADAY. No, sir. I could not put any of them in that category. I think we are considering actively all of them.

Mr. VOLKMER. Do you have a timetable as to when you decide you will follow those recommendations? In other words, make a decision as to what part of them you will accept?

Dr. COLLADAY. I would say, as Dr. Martin gets up to speed and is able to deal with and make a major input into those decisions, that will come over the period of the next 6 months.

Mr. VOLKMER. In regard to that, as far as research policy, what we are seeing a vision of in the future is possibly manufacturing in space, electropheresis, and other materials and alloys and what have you. Is there any discussion going on within OAST as to possible involvement with industries that are contemplating those types of things in their research, determining areas of research?

Dr. COLLADAY. That dialog with the industry is really what is taking the time for our deliberate considerations. The way we interact with the spacecraft industry and support their plans and capability for stronger private-sector commercialization is something that comes very natural to us in aeronautics. We have a long history of that relationship. We are trying to build that same kind of interaction with the industry in the space technology program. It is difficult.

Mr. VOLKMER. I want to congratulate you on that. I think that needs to be done.

I have no further questions. Do you have any further statements you would like to make, Mr. Martin?

Dr. MARTIN. No, sir, just to express appreciation for being here.

Mr. VOLKMER. I guess I could ask you one on the space nuclear energy research that is ongoing with DOD and Energy. I do not want to get a timetable in here, but I would like to get some idea of where we are, if you can answer that. In other words, what does it look like? If we need that much energy, if we go to something by the year 2000 for needs of, let's say, over 200 kilowatts, are we going to be able to do it?

Dr. COLLADAY. We are making excellent progress, after a fairly shaky start, as you know, of getting the management team together. We are on the same time schedule that we had indicated to you 1 year ago, and that is an intense 2-year period of technology development, leading to a decision for major ground engineering phase in 1986. I still think we can meet that milestone, and then the development cycle beyond that would put us in a position of having a usable capability in the midnineties. That is about where we think we need to be.

Mr. VOLKMER. I agree on that. Thank you very much for being here today. I am sorry you had to wait so long. We look forward to working with you in the research field.

[Whereupon, at 12:55 p.m., the hearing adjourned, to reconvene sine die.]

1985 NASA AUTHORIZATION

TUESDAY, FEBRUARY 7, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 1:10 p.m., in room 2325, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Present: Representatives Volkmer, Nelson, MacKay, Winn Lujan, Lowery, Bateman, and Walker.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

Today, we continue with the NASA authorization hearing for the 1985 budget. Over the next 3 days, we will focus on the space science and applications program which accounts for about 18 percent of the budget request.

Space science and applications is a particularly important part of the NASA budget this year for several reasons. In the space science and applications area, we find a major reason for NASA's existence. NASA is a mission-oriented agency and, as such, must continue to develop the means to utilize space in an efficient and low-cost manner for the benefit of all mankind. We must never lose sight of the fact that space-based systems such as the space shuttle and proposed space station are one means of achieving our scientific objectives. These objectives should remain as an important identifiable focus for NASA, and should be embodied in a vigorous space science and applications program.

We must always ensure that major investments in space transportation systems are balanced by an aggressive science and applications program to take full advantage of the access to space afforded by such system. At times, achieving such a balance might require additional resources to be allocated to selected science and applications programs.

Today, we will examine these programs in depth. We will look at past major efforts such as the IRAS mission and ask ourselves, where to go from here? We will hear about some new initiatives such as the Mars geoscience/climatology orbiter and the upper atmospheric research satellite. We will also wish to review the progress of ongoing efforts such as the Hubble space telescope.

In view of the experience gained with spacelab I, I believe it is appropriate to examine the broad issue of how science is best served by the space transportation system. Of equal importance, what can individual investigators in the academic community and

elsewhere expect in terms of research opportunities with this new national asset?

Our first witness today is Dr. Burton Edelson, Associate Administrator for Space Science and Applications, National Aeronautics and Space Administration. He will be followed by Dr. Thomas Donahue, Chairman of the Space Science Board of the National Academy of Sciences.

Dr. Edelson, before you begin your testimony, I would first like to ask unanimous consent that photography be permitted during the session today. If there are no objections, then that will be permitted.

[No response.]

I now recognize the gentleman from New Mexico for an opening statement.

Mr. LUJAN. Thank you very much, Mr. Chairman, and Dr. Edelson, welcome to the committee.

I was pleased to see the two new initiatives in the budget request for your office, the Mars observer and the upper atmosphere research satellite. Between these two, they represent several key points about the mission of NASA. The Mars orbiter, of course, will be another step in the exploration of the solar system. It is the first planetary observer mission as recommended by the Solar System Exploration Committee.

Definitely, these exploration activities should be a key part of U.S. space program, so I applaud this new start as another step in the right direction.

The UARS will provide us with data toward the expansion of our knowledge and understanding of the earth's upper atmosphere. Understanding global weather patterns and better management of our resources—the atmosphere, in this case—will benefit not just U.S. citizens but the rest of the world as well, and is an appropriate part of NASA's mission.

I believe that these two programs are the type of basic R&D that should be the top priorities for our Federal R&D budget.

This leads me to one point. As you know, I have been a strong supporter of the space station and was one of those who urged the President to approve it. I believe that the space program has driven the technology development for new industries, and that the future economic strength of the United States will be enhanced by the space station. But I also feel that the space station has more intangible benefits.

It has been said that the Space Science Board did not see an advantage of the space science station for space science programs. I believe there might be some justification in that reluctance, since we have seen the valuable funding resources diverted from the space shuttle development. We will have to make certain that the lessons learned from the shuttle program are applied to the space station so that we make it possible for science and application programs to take full advantage of those space capabilities.

In the final analysis, I suspect that the shuttle is proving itself to be a real asset for space scientists. More importantly, I feel it is our responsibility, mine and the other Members of the Congress, to reassure space scientists that they will have our support for a strong program parallel with, not after, the development of the space sta-

tion. We will have to see that these programs receive strong funding support and are not the victims of operational programs.

I look forward to discussing these issues further during the afternoon and, again, welcome to the committee.

Thank you very much, Mr. Chairman.

Mr. VOLKMER. Thank you.

Does the gentleman from Virginia have any statement he wishes to make?

Mr. BATEMAN. No, Mr. Chairman.

Mr. VOLKMER. The Chair will recognize that we have also with us today the ranking minority member of the full committee, Mr. Winn from Kansas. It is a pleasure to have him here with us.

It is also a pleasure, Dr. Edelson, to have you and Mr. Konkel and Mr. Keller here to testify today. We look forward to your testimony. Your statement which you have been so kind to furnish a copy of and which I have examined will be made a part of the record in full, and you may review the statement or summarize it, however you so desire. Without objection, that statement will be made a part of the record.

You may proceed, Dr. Edelson.

STATEMENT OF DR. BURTON I. EDELSON, ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE AND APPLICATIONS OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY RONALD M. KONKEL, DIRECTOR, ADMINISTRATION AND RESOURCE MANAGEMENT DIVISION, OFFICE OF SPACE SCIENCE AND APPLICATIONS; SAMUEL W. KELLER, DEPUTY ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE AND APPLICATIONS; DR. JEFFREY D. ROSENDHAL, ASSISTANT ASSOCIATE ADMINISTRATOR FOR SCIENCE, OFFICE OF SPACE SCIENCE AND APPLICATIONS; AND RICHARD HALPERN, DIRECTOR, MICROGRAVITY SCIENCE AND APPLICATIONS DIVISION, OFFICE OF SPACE SCIENCE AND APPLICATIONS

Dr. EDELSON. Mr. Chairman and members of the subcommittee, it is a real pleasure for me to be here today to present and to discuss the fiscal year 1985 budget request for the NASA Office of Space Science and Applications. I will submit, as you suggested, for the record, my written statement and I will now briefly review the salient points of the presentation orally.

The program we are proposing for fiscal year 1985 will continue the tradition of scientific achievement and excellence that the Nation has come to associate with the space program generally and, I believe, with the science and applications program in particular. This program will maintain U.S. capability and leadership in the pursuit of scientific knowledge and the application of that knowledge and technology to national needs. We are presenting what we believe to be a balanced program, continuing the ongoing flight programs, adding new initiatives, preserving the research base, and planning for the future. Our program continues the utilization of the space shuttle for science and applications missions, and it looks forward to the use of the manned space station and its associated platforms to evolve future science and applications missions.

Mr. Chairman, the space science and applications program is a multifaceted one. It involves many disciplines of science and engineering. It has multiple goals: to create scientific knowledge, to push technology and develop new capabilities, and to apply these for the benefit of this country and for all mankind. As we strive to meet these goals, we concern ourselves with the study of the entire universe and our more immediate cosmic neighborhood, the solar system. We are trying to understand the Earth as a system, and to learn about the dynamic processes that influence the atmosphere, the hydrosphere, the biosphere, and the geosphere. We are also involved in biomedical research, in microgravity science and applications and the development of technology to improve satellite communications and remote sensing. We also use remote sensing techniques to advance our understanding of the Earth as a system.

Before I discuss the details of the budget, I would like your permission to briefly highlight two notable achievements of the past year.

The infrared astronomical satellite [IRAS], a cooperative program with the Netherlands and the United Kingdom, was a spectacular success. It was launched in January 1983, as shown here (fig. 1) on the Delta launch vehicle. It operated well into December at which time the cryogenic fluid was expended.

[Figures 1-8 appear at the end of Dr. Edelson's prepared statement, see p. 257.]

This next slide (fig. 2) shows a comparison of the view toward the center of our galaxy in the visible light and the improvement in data return from IRAS, conventional on the right, IRAS on the left. Infrared radiation passes freely through the dust that obscures our view of our own galaxy in visible light. On the left portion of the slide is a infrared picture from IRAS showing the central 50 degrees of our galaxy. The regions of cold interstellar clouds appear red. The regions of active star formation appear blue. On the other, right portion of the slide, we see the same area in visible light. In it the galaxy looks thicker because we can see only the nearest portions. The visible light view of the center of the galaxy is completely blocked.

On the next slide (fig. 3), we depict some of the discoveries made by this outstanding mission. Mining the IRAS data for discoveries has really just begun. Look at the activity behind the familiar constellation Orion. This is one of the many regions of active star formation in our own galaxy.

IRAS has also found several examples of systems of small particles in orbit about stars that are clearly related to the formation of planets. This is opening up an avenue of investigation into the formation of stars and planets that was never before available. Finally, IRAS was a tremendously successful comet hunter, and has shown us that comets are far dustier than we had previously believed.

Altogether, IRAS was successful from a scientific point of view, from an engineering point of view, and from an international cooperation point of view.

Spacelab I, another mission and another major achievement of the past year and the second one that I will mention today. Launched in November 1983, it was the first flight of this versatile

facility built by the Europeans. The mission carried 71 investigations provided by the United States, Europe, Japan, and Canada. Experiments were performed in microgravity sciences, life sciences, astronomy and solar physics, plasma physics, atmosphere and earth sciences.

What we see here is the spacelab (fig. 6) inside the shuttle bay during the mission. If it were a little brighter, you could see both the NASA logo and the ESA logo on there, highlighting again that this is an international cooperative program.

The next slide shows one of the payload specialists (fig. 4), in this case Dr. Ulf Merbold of Germany, carrying out one of the experiments using the gradient heating facility in the materials science double rack.

The next is Dr. Byron Lichtenberg (fig. 5), the other payload specialist, of MIT, participating in the vestibular spinal reflex experiment. He investigates the reflexes associated with the vestibular response and their relationship to space motion sickness.

The handle, the T-bar handle he is holding will be released and he will be pulled down by the bungee cords attached to his waist and the floor to accelerate him at a 1g level. The electrodes attached to his legs will stimulate and record responses to mild electric shocks before he hits the floor. That is the response that a cat goes through as it falls through the air. The accelerometers are also attached to various parts of his body and data recorded on the tape recorder of his belt. This data is used to evaluate changes that occur in his vestibular response as a result of weightlessness. The obvious purpose here is to get some understanding of space adaptation, in particular, to cause the problem that we have had with space motion sickness.

The spacelab I mission which I have just highlighted has proven the viability and value of the space lab to support scientists working in space performing experiments in the five disciplines that I mentioned. It also gives us a glimpse at the potential we will realize with the NASA space station. We are looking forward to a number of significant events during this coming year of 1984. Our next mission, in April, we plan to conduct the solar max repair mission based upon the 41-B flight just now in progress. In August we will launch the AMPTE, active magnetospheric particle tracer explorer. In November we plan to launch spacelab III which will carry a large array of life science and microgravity experiments.

I would like now to turn to the fiscal year 1985 budget request (fig. 7). Having set the stage in a comfortable mode, I hope, with past accomplishments and some of the future events, we are going to look forward a year to fiscal year 1985.

Let me begin by noting that the two new initiatives are the upper atmosphere research satellite [UARS], and the Mars geoscience climatology orbiter which I will refer to as the Mars orbiter or MGCO.

UARS is an important step in conducting a comprehensive program of research of the upper atmosphere. It is a major element of our Earth sciences program. UARS will provide the first integrated global measurements of ozone concentration, atmospheric constituents and species, temperatures, and winds. UARS is critical to our overall stratospheric research and monitoring effort, and it will

provide the first full data set on the interaction of stratospheric composition and dynamics.

The Mars orbiter represents a return to the red planet, Mars, which will extend and complement the data acquired by our previous Mariner and Viking missions. MGCO is a relatively low-cost inner solar system mission designed to use a modified Earth orbital spacecraft. The Mars orbiter will map the global surface composition distribution of ice on the surface and water in the atmosphere, the topography, the figure, gravity and magnetic fields of Mars. This mission is the first of a new class referred to as planetary observers and recommended by the Solar System Exploration Committee.

I would like to turn now to the detailed fiscal year 1985 budget for science and applications (fig. 8). To make it easier for you to read the Vu-Graph, I have listed here the major budget categories. The next level of detail is appended to the written statement and has been distributed to you earlier.

Our total fiscal year 1985 research and development request is $1371.5 million. I believe this funding level, up almost 21 percent over fiscal year 1984, represents a good program, a well structured and balanced program in the various space science and applications disciplines.

This request will support the continuation of our ongoing flight programs: the Hubble space telescope, the Galileo mission to Jupiter, the U.S. participation in the ISPM, the Gamma Ray Observatory, and others. In fiscal year 1985 we plan to step up funding for the Venus radar mapper development which we are starting this year.

We will continue the advanced technology communications satellite program, ACTS, as a ground-based technology effort. We will develop and provide a scaterometer radar for the U.S. Navy remote ocean sensing satellite. We will continue to work on a number of our explorer missions. This budget request also supports instrumentation and mission management activities for spacelab 2, 3, and 4, and many other shuttle missions.

The proposed 1985 budget also supports a broad spectrum of research activities in several disciplines. These encompass astrophysics, solar system exploration, Earth sciences, life sciences, microgravity science and applications, and communications.

We are requesting $677.2 million for our physics and astronomy program. I am sorry, I am starting in the middle and working down, and I will take applications last. The physics and astronomy line item includes $195 million for the Hubble space telescope development. Integration and testing of the optical telescope assembly will be completed in fiscal 1985 and delivered to Lockheed where system integration and testing will be undertaken. A particularly encouraging milestone during the year was the development and testing of the fine guidance sensor, part of the OTA, and the delivery of the five scientific instruments to Goddard Space Flight Center.

We are pleased with the progress this past year. We are, however, still facing many challenges over the next 2 years before launch. This is particularly true in the ST development, integration, and testing. We still have to complete verification and accept-

ance of all five scientific instruments. We still need to integrate the optical control system with the fine guidance sensor, install and aline the primary mirror, and complete the support system module. I am optimistic, and I believe that these efforts, I can assure you that these efforts are receiving very intense management attention.

We are requesting $120.2 million for the gamma ray observatory development in fiscal year 1985. This funding will support continuation of the major fabrication and assembly efforts on both instruments and the spacecraft leading to a launch in 1988.

Our Explorer development request of $51.9 million will continue development of AMPTE, the active magnetospheric particle trancer explorer and COBE, the cosmic background explorer. We are also developing instruments to be flown on the German Roentgen satellite, ROSAT, which will fly in 1987.

Turning now to planetary exploration, our fiscal year 1985 request is $286.9 million, up 32 percent over fiscal year 1984. This program includes $16 million for a new initiative, the Mars orbiter which I mentioned. The Mars orbiter will be launched in 1990 and will go into orbit around Mars in 1991. Its instruments will scan the Martian surface and probe the atmosphere. It will collect data on the surface composition, atmosphere, magnetic field, and sources of and movement of volatiles and dust.

We are requesting $56.1 million for the ongoing Galileo development program to support activities leading to a planned launch in 1986. We have completed integration tests on both the atmospheric probe and the orbiter and are currently studying options to deal with a potential radiation problem at Jupiter which we have analyzed. The parachute system for the probe was successfully tested. In fiscal year 1985 we will complete integration of the orbiter and probe. We will then test the fully integrated system of Galileo.

The request of $92.5 million for Venus radar mapper development will support completion of design efforts for the spacecraft and the radar system. It will also support the fabrication and testing of the radar development test model.

We will also continue to support the operational spacecraft in the planetary exploration MO&DA line. These are the Voyagers, the Pioneer-Venus orbiter, and Pioneers 6 through 11. A notable highlight in this area during the past year was the departure from the solar system last June by Pioneer 10. This was the first human artifact to leave the solar system and is now entering that unexplored region where the Sun's magnetic field disappears into true interstellar space. Voyager 1 will encounter Uranus in 1986.

Our fiscal year 1985 request for life sciences is $63.3 million. This will continue to support a program of biomedical research that provides a sound scientific medical and technical basis for safe and productive manned space flight. The life sciences program is a key element in developing our capability to attain a permanent manned presence in space.

Our total request for space applications, going now to the top of the viewgraph, is $344.1 million. This will continue a balanced and aggressive program in solid Earth observations, environmental observations, microgravity science and applications, communications,

and information systems, all subheadings under the budget line item of applications.

In environmental observations, our major new effort is, as mentioned, the upper atmosphere research satellite. UARS is a critical part of our overall stratospheric research effort. It will provide integrated measurements of ozone concentration, chemical species, temperatures and winds in the upper atmosphere. UARS is planned for launch in 1989.

Also in the environmental observations program, we will develop a scatterometer, a radar for use by the Navy on their N-ROSS satellite. The scatterometer will provide accurate, global measurements of ocean surface winds which will be useful both for oceanography and meteorology.

In our solid Earth observations program, we will continue activities needed to develop space observations and experimentation techniques to further understanding of the global, physical, chemical, and biological processes of the Earth.

In microgravity science and applications, a new title for materials processing in space to connote a broader scope, we will continue to perform research in areas where microgravity plays a significant role in the basic processes. We will continue ground-based research and support commercialization activities. Three instruments, the isoelectric furnace, the MLR, and the ASIS program, are just now in orbit on the 41–B flight, and all indications are that they are operating properly.

In communications, we will continue to support the development of component and device technology, technical consultation, and the search and rescue program. The ACTS program is designed to develop advanced satellite communication technologies. As you know, originally we had planned to fly the ACTS satellite to provide a flight test. However, in view of private sector activity in commercial systems, we have restructured our plans to continue the ACTS program as a technology and development ground-based effort.

This budget request continues to support our critical research and analysis and suborbital research programs in all areas. These supporting programs provide the foundation for our orbital and deep space flight programs.

The program balance can be seen in this pie chart which indicates, on the right, that some 57 percent of the effort in fiscal year 1985 will go into flight programs and about 43 percent into the research base on the left.

Before I conclude my statement, Mr. Chairman, I would like to mention several potential new missions. We have an extensive planning activity in OSSA, closely coordinated with the science and applications communities and our various advisory boards, such as the Space Science Board, the Space Applications Board, the NASA Advisory Council and their various committees.

Some of the missions that are high on our priority list are: TOPEX, the ocean topography experiment, which would provide the basis for improving our understanding of the general circulation of the world's oceans; the ISTP program, the international solar terrestrial physics program which we are currently planning with ESA and ISAS, the Japanese space agency, to cover solar and

heliospheric physics and magnetospheric physics; the shuttle intrared telescope facility, a meter-class, cryogenically cooled observatory that would be much more sensitive and versatile than IRAS; the advanced X-ray astrophysics facility, AXAF, the number one astronomy priority mission which would be a very powerful observatory dedicated to the investigation of almost every astronomical object in this very fruitful part of the electromagnetic spectrum; a comet rendezvous mission, a Mariner-Mark II mission, very highly recommended by the Solar System Exploration Committee; not to mention the agency's major new initiative, the manned space station.

Our office has been heavily involved in definition activities for the space station. We have established very close links with the space station task force in NASA and have conducted our own analyses and definitions. I foresee many uses of the space station in science and applications.

We plan to use the manned laboratory module, which is part of the manned space station, to conduct microgravity and life science experiments. We plan to use the coorbiting platform sometimes known as the astro platform, to serve our astrophysics efforts, such as starlab or other telescope systems. We expect to use the polar unmanned platform to support our remote sensing activities. The space station will also provide a servicing facility for science and applications spacecraft such as the space telescope and the gamma ray observatory. Also, the space station will serve as a major staging base to enable future science and applications missions such as large geostationary orbit platforms and major planetary missions. The space station will be a particularly important facility for space science and applications in the years to come.

Thank you, Mr. Chairman. I will be happy to answer any questions you may have.

[The prepared statement, plus answers to questions asked of Dr. Edelson follows:]

Statement of

Dr. Burton I. Edelson
Associate Administrator for
Space Science and Applications

National Aeronautics and Space Administration

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

It is a pleasure to be here today to discuss with you the proposed FY 1985 budget for the Space Science and Applications program. The program I am proposing will continue the tradition of scientific achievement and excellence which the nation has come to associate with the space program. It will maintain U.S. capability and leadership in the pursuit of scientific knowledge and new applications of space technology to national needs.

The Space Science and Applications program is multifaceted. It involves many disciplines of science and engineering. It has many goals and objectives: to create scientific knowledge, to push technology and develop new capabilities, and to apply these technologies and capabilities for the benefit of this country and of all mankind. As we strive to meet these goals, we concern ourselves with the study of the entire universe; our more immediate cosmic neighborhood, the solar system; the applications of space technology to understand the Earth and the dynamic processes that influence the atmosphere, hydrosphere, biosphere and geosphere; the utilization of microgravity in materials processing; life sciences research to develop foundations for a human permanent presence in space; the development of technology to improve communications; and the use of remote sensing techniques to advance our understanding of the Earth as a total system. We are also concerned with and involved in the challenges presented by manned space flight and the establishment and utilization of a space station and its associated science and applications platforms.

HIGHLIGHTS OF THE PAST YEAR

Before discussing the budget, I would like to review a few of our many achievements over the past year and preview some of the major activities planned for the current year. Accomplishments such as these, in the final analysis, are the real justification for the Space Science and Applications program.

IRAS

One of our successes of 1983 was the tremendous scientific return from the international Infrared Astronomical Satellite, IRAS,

a cooperative program with the Netherlands and the United Kingdom. When I spoke to you last year, IRAS had just been launched, and we knew only that the satellite and its instruments were working very well. Now I can tell you that after only a few percent of the data have been examined, it is clear that enormous advances in our understanding of the universe will emerge from this program.

The IRAS all-sky survey had a set of very ambitious requirements that were met or exceeded. The survey required that each infrared source in the catalog have an extremely high probability of being a true astronomical object (reliability), that the vast majority of true astronomical objects in any area covered by the survey be found and cataloged (completeness), and that 96% of the sky be surveyed twice. Our analysis of the data to date indicates that we will achieve a 99.9% reliability, greater than 97% completeness, and that the satellite surveyed 95% of the sky twice and 72% a third time before it ceased operating. In addition, approximately 10,000 individual detailed observations of celestial objects were made. The unprecedented sensitivity of IRAS in the infrared has allowed us to peer into this previously unexplored gap in the electromagnetic spectrum. The number of infrared sources cataloged prior to the IRAS launch was approximately 1,000; the new catalog will have over 225,000 sources including 20,000 new galaxies.

IRAS recorded data on the formation of stars throughout our galaxy, discovered five new comets, and found a new asteroid (which may possibly be a dead comet) that passes closer to the Sun than any planet or known asteroid. With IRAS, we discovered systems of particles around the star Vega and several other stars that appear to be related to the formation of planets in these systems, clouds of dust above and below the Sun in the plane of the Galaxy, and three giant dust shells asymmetrically placed around the star Betelgeuse. Overcoming the substantial technical challenges presented by the IRAS mission has paid off handsomely in scientific return, and we and our international partners--the Netherlands and the United Kingdom--can be proud of the dramatic success of IRAS. There is no doubt that IRAS will be a landmark in the history of astronomy.

Pioneer 10

Pioneer 10 was launched on March 2, 1972. On June 13, 1983, the spacecraft passed the orbit of Neptune; at present, Neptune is the most distant planet from the Sun. Pioneer 10 has become the first human artifact to leave the solar system. The spacecraft will continue to send back data for the next several years with the immediate mission of detecting the heliopause, the distant boundary between the region of space controlling the Sun's magnetic field and true interstellar space. The spacecraft is now more than 30 Astronomical Units (AU) from the Sun and is moving outward at 2.8 AU/year. The round-trip communication time between Earth and the spacecraft is now over eight hours. Its power and communications capabilities should enable the acquisition of data to about 50 AU, a distance it should reach in 1991.

Spacelab 1

The first Spacelab mission was launched on November 28, 1983. Besides being the first launch of this very versatile, European-built facility, Spacelab 1 achieved many other important firsts. Among these were: the first launch of a six man crew which allowed around-the-clock scientific operations; the first non-career astronauts to fly in space (including Dr. Ulf Merbold from Germany); the first direct interaction of the space crew and ground-based scientists; the first use of the TDRSS; the first use of the full-up Spacelab Payload Operations Control Center at the Johnson Space Center; and the first use of the Spacelab Payload Data Processing Facility. It was the longest Shuttle mission to date. This highly successful, cooperative mission with the European Space Agency carried 71 investigations provided by the U.S., Europe, Japan, and Canada. Valuable scientific data was obtained in astronomy, solar physics, plasma physics, life sciences, materials sciences, atmospheric physics, and earth resources. Spacelab 1 was the culmination of nearly 10 years of work in the U.S. and Europe, and the beginning of a new era of space science capability.

This ambitious mission has proven the capabilities of the Spacelab and its support facilities to support several scientific disciplines. The multidisciplinary character of the Spacelab 1 demonstrated the scientific utility and versatility of Spacelab, and provided enhanced observational opportunities, increased environmental control, and extensive crew interaction. Scientists in the Payload Operations Control Center (POCC) collaborated closely with the crew in scientific activities, and their efforts served to enhance the scientific yield of the mission.

The data from Spacelab 1 are now being analyzed. Already, it is clear that some important scientific results have been attained. For example, in atmospheric physics we obtained a database for a detailed assessment of the Shuttle environment for optical remote sensing in the visible, ultraviolet and near infrared; the mission conducted the first floating zone crystal growth experiments, and observed for the first time in space the movement within a two element system driven by surface tension (Marangoni Flow). Spacelab 1 proved the importance of "man-in-the-loop." The crew repaired and restored several instruments to a fully operational state. They removed jammed film from the metric camera using an improvised dark room; removed a materials processing sample lodged in the Isothermal Heating Facility to permit processing of other samples; and rerouted cables enabling the Mirror Heating Facility to conduct its planned science. The availability of people to make repairs and adjustments demonstrated the advantages of manned flight and ushered in a new way of doing science in the unique environment of space. Clearly, the outstanding success of Spacelab foreshadows the potential of the manned Space Station.

International Cometary Explorer (ICE)

On December 22, 1983, the International Sun-Earth Explorer (ISEE-3) departed Earth orbit on the final phase of its escape trajectory to encounter comet Giacobinni-Zinner in September 1985.

We have renamed ISEE-3 to International Cometary Explorer (ICE) after its orbit was manipulated last year so that we may gather some cometary science; and expect that ICE will return new and exciting information regarding the components of a comet tail. We view this as an excellent example of our ability to find ways to obtain innovative science from our older spacecraft.

UPCOMING EVENTS

We are looking forward to a number of significant events this year, and I would like to mention a few of these. In April, we plan to conduct the Solar Maximum Repair Mission. This will be the first retrieval and repair of a spacecraft using the Shuttle, and will demonstrate a major new capability while simultaneously restoring the Solar Maximum Mission spacecraft and instrumentation to full operating capacity to investigate the physical events occurring in solar flares. In August, we plan to launch the Active Magnetospheric Particle Tracer Explorer (AMPTE). This is an international effort involving the Federal Republic of Germany and the United Kingdom. AMPTE will allow us to study the solar wind at the subsolar point and to identify particle entry windows and energization and transport processes into the magnetosphere. We also look forward to the launch of Spacelab 3 in November 1984. This mission will carry a large array of life sciences and space applications experiments. We will launch Landsat D' for NOAA next month; the Earth Radiation Budget Satellite will be launched by the Shuttle in August 1984; and the San Marco-D mission, a cooperative project with Italy to study the relationship between solar activity and Earth's meteorlogical phenomena, will be launched in December.

These are only a few of many important activities we plan in space science and applications during the current year. I simply highlighted these to give you an example of the diversity of the Space Science and Applications program.

NEW INITIATIVES

Before turning to the overall FY 1985 budget request for Space Science and Applications, I would like to briefly mention the two new initiatives that we are requesting: the Upper Atmosphere Research Satellite (UARS), and the Mars Geoscience/Climatology Orbiter (MGCO).

The Upper Atmosphere Research Satellite (UARS) is the next logical step in conducting a comprehensive program of research, technology development and monitoring of the upper atmosphere to improve the basic scientific understanding of the effect of mankind on our atmosphere. This mission will provide the first integrated global measurements of ozone concentration, chemical species that affect ozone, energy inputs, temperature, and winds in the stratosphere and mesosphere. UARS is a critical element in NASA's overall stratospheric research and measuring efforts, and will provide the first full data set on stratospheric composition and dynamics.

The Mars Geoscience/Climatology Orbiter (MGCO) is a relatively low-cost inner solar system mission which will utilize a modified Earth-orbital spacecraft, and will conduct a tightly focused science objective. MGCO, the first of a new class of lower cost missions referred to as "Planetary Observers" by the Solar System Exploration Committee, will extend and complement the data acquired by the Mariner and Viking missions by mapping the global surface composition, topography, figure, gravity and magnetic fields of Mars. This mapping is required to determine the location of volatile reservoirs and characterizations of their interaction with the Martian environment. This will allow us to determine better the complex geologic and climatic history of Mars and relate these to the history of Earth. MGCO is targeted for launch in 1990 with the Space Shuttle, which will result in the spacecraft being inserted into Martian orbit in 1991.

BUDGET REQUEST

The total FY 1985 Research and Development request for the Office of Space Science and Applications is $1371.5 million. This funding level respresents a well-structured and balanced program in various Space Science and Applications disciplines.

This budget request will support the continuation of the Hubble Space Telescope development effort, leading to a launch in the second half of 1986; it allows for continued development of the Galileo mission to Jupiter which will be launched on the Shuttle/Centaur combination in 1986; allows for continuation of U.S. participation in the International Solar Polar Mission also planned for launch on the Shuttle/Centaur in 1986; provides for the continued development of the Gamma Ray Observatory (GRO) for launch in 1988; and continues the Venus Radar Mapper (VRM) development activities for launch in 1988. In this budget we will carryout the Advanced Communications Technology Satellite (ACTS) effort as a ground-based technology development and test program. We will develop and provide a Scatterometer radar for the U.S. Navy Remote Ocean Sensing Satellite (N-ROSS). We will continue work on our explorer program. This budget also supports the development of instrumentation and associated mission management activities for the Spacelab 2, 3, 4 and other Shuttle missions. In addition, this funding level allows a broad spectrum of research activities and scientific inquiries into many basic scientific disciplines encompassing astrophysics, astronomy, solar system exploration, Earth science and applications, life sciences, microgravity science and applications, communications technology and information systems.

The details of the FY 1985 Space Science and Applications budget request are displayed in Charts #1 and #2. I will now briefly review the content of each of the major elements of the budget.

PHYSICS AND ASTRONOMY

In our Physics and Astronomy program, for which we are requesting $677.2 million, we investigate the physical universe to determine the structure, dynamics, and life cycle of the Sun, stars,

galaxies, and the universe itself. The investigations are made by observing the cosmic rays, infrared, visible, and ultraviolet light, X-rays and gamma rays that come to the earth from the incandescent surface of the Sun, other stars and galaxies, from quiet clouds of interstellar gas, and from explosions as large as the Big Bang. We are now in a time when some of mankind's oldest questions about the universe in which we live can be investigated and possibly answered.

Hubble Space Telescope

The Hubble Space Telescope, for which we are requesting $195.0 million in FY 1985, is a collaborative program with the European Space Agency (ESA). It will be the first major observatory in space and a centerpiece of international astronomical research for many years to come. When it is launched in 1986, the Space Telescope will allow scientists to take the greatest single leap in optical astronomical capability since the first telescope was used for astronomy by Galileo in the early 1600's; almost every field of astronomical research will be directly affected by this tremendous increase in observational capability. Scientists will be able to study the long-term atmospheric trends in most of the planets of the solar system including Venus, Mars, Jupiter, Saturn, Uranus, and Neptune. The Hubble Space Telescope will also permit studies of a vast range of solar-type stars beyond our solar system, which could lead to a better understanding of our own Sun's variable activity. The ability to probe deep into the universe, thus far back in time, will give scientists a much clearer picture of how galaxies evolve from clouds of diffuse gas into the variety of forms we observe today.

Integration and testing of the Optical Telescope Assembly will be completed in FY 1985 and subsequently delivered to Lockheed Missiles and Space Company where the entire Space Telescope system integration and testing will be undertaken. A particularly encouraging milestone during the past year was the significant progress associated with the Fine Guidance Sensor (FGS) development. Testing of an engineering model of the FGS has shown that optical and mechanical design concerns have been alleviated and we are now confident that the FGS will perform its critical function--to lock onto faint guide stars and point with extremely high accuracy. The five ST scientific instruments have been delivered to the Goddard Space Flight Center and are currently undergoing verification and acceptance testing. This testing is scheduled for completion in mid-1984. The ST Science Institute at the Johns Hopkins University in Baltimore, Maryland has been completed and good progress is being made on the staffing, the development of the Guide Star Selection System and the Science Data Analysis System.

We are pleased with the progress of this past year. We are however, still facing many challenges over the next two years with the continued ST development, integration, and testing. Some of the major milestones include completing verification and acceptance testing of all five Scientific Instruments (SIs), integration of the Optical Control Subsystem (OCS) with the Fine Guidance Sensor, installation and alignment of the Primary Mirror Assembly,

completion of the Support System Module, and continued software development for the Science Operations Ground System. All of these efforts are receiving intense management attention and while some technical hurdles have been overcome, we will be faced with some difficult challenges over the next two years before the planned launch in 1986.

Gamma Ray Observatory

We are requesting $120.2 million for the Gamma Ray Observatory (GRO) development in FY 1985. The objective of GRO is to measure gamma radiation from the universe, and to explore the fundamental physical processes powering it. GRO is scheduled for launch by the Space Shuttle in 1988. It will accommodate four large gamma ray instruments, and is being designed for maintenance and retrieval by the Space Shuttle. FY 1985 funding will support continuation of the major fabrication and assembly efforts on both the instruments and the spacecraft leading to the mission critical design review. The preliminary design review (PDR) on the instruments was successfully conducted during 1983 and the spacecraft PDR is scheduled for mid-1984. The GRO development efforts are on schedule and within cost.

Explorers

NASA currently has two explorers in the development phase; the Active Magnetospheric Particle Tracer Explorer (AMPTE) scheduled for launch in 1984 and the Cosmic Background Explorer (COBE) scheduled for launch in late 1987/ 1988. NASA is also developing instrumentation which will be flown on the German Roentgen Satellite (ROSAT) in 1987 to study galactic and extra-galactic X-ray sources. In addition, design and development will also be initiated in FY 1984 on the Extreme Ultraviolet Explorer (EUVE).

Cosmic Background Explorer

The Cosmic Background Explorer (COBE) is being developed for a sensitive observation of the diffuse infrared and microwave background radiation which is the primary remnant of the Big Bang. By observing the spectrum and structure of the radiation, we will be investigating the conditions in the universe which are believed to be near its very beginning. The FY 1985 funding will support development activities leading to a launch in late 1987 or early 1988. Major fabrication activities are being continued in FY 1985 leading to the initial hardware assembly in 1985. COBE is a particularly difficult technical challenge in view of the need for special cryogenic cooling and precise pointing and sensitivity, thus we continue to work very hard on this exciting mission during FY 1984 and FY 1985.

Active Magnetospheric Particle Tracer Explorers

Development of the Active Magnetospheric Particle Tracer Explorers (AMPTE) is proceeding on schedule for launch in August 1984. AMPTE is an international effort involving the Federal

Republic of Germany and the United Kingdom. Germany is providing an Ion Release Module (IRM) spacecraft which will release tracer ions outside the Earth's magnetosphere, and the United Kingdom is providing a subsatellite which will orbit close to the IRM and sense the ions at the point of release. The United States is developing a Charge Composition Explorer spacecraft which will detect the entry and energization of these tracers inside the magnetosphere. All three satellites are fully integrated and are currently undergoing environmental testing.

Roentgen Satellite

The Roentgen Satellite (ROSAT), a cooperative project between the Federal Republic of Germany and the United States, will perform high resolution imaging studies of the X-ray sky. The U.S. will provide a high resolution imaging instrument and launch on the Space Shuttle, and Germany will provide the spacecraft plus other required instrumentation. ROSAT is scheduled to be launched in 1987.

Extreme Ultraviolet Explorer

This year we will initiate design and development activities on the Extreme Ultraviolet Explorer (EUVE) leading to a launch in 1988. The extreme ultraviolet lies between ultraviolet and X-rays and is the preferred wavelength of emission for gas near 100,000 degrees. The coronae of stars are at this temperature, and stars in their final stages of evolution are expected to be copious sources of extreme UV radiation. Only 10 cosmic sources of extreme UV are presently known, and when the extreme UV window is opened, we anticipate many surprises like those discovered by IRAS.

Solar Maximum Mission Repair

The Sun is our nearest star and is available for study at a level of detail unattainable with other stars. As an example, recent comparison of X-ray burst data from SMM and ground-based radio data has once more emphasized the small scale at which astrophysical plasma processes are operating. The observations found that flare arches are only 20,000 to 30,000 km in size and that the primary flare site at the top of the arch where the electrons are accelerated must be only one tenth that size, or only about 2500 km.

Repair of the SMM is scientifically very important. The primary objective of this mission was to investigate the physical events occurring in a solar flare, and the results to date have indeed confirmed the broad outline of a tenable flare model. This year we will conduct a mission to restore the SMM spacecraft and instruments to their full operational capacity. The SMM spacecraft was designed to use the unique capability of the Space Shuttle for repair in orbit; it will be the first demonstration of this new capability. The Repair Mission will be conducted in April 1984.

PLANETARY EXPLORATION

The FY 1985 Budget Request for Planetary Exploration is $286.9 million. Included in this request is $16.0 million for a new initiative, the Mars Geoscience/Climatology Orbiter.

The Mars Geoscience and Climatology Orbiter (MGCO) will be a return to the Red Planet--Mars. The MGCO will be launched in 1990 and will go into orbit around Mars in 1991. Orbiting above Mars, its instruments will scan the martian surface and probe the martian atmosphere to collect data on such unanswered questions regarding the global surface composition of Mars, its atmospheric circulation, its magnetic field, and the sources and movements of dust and volatiles through its air and across its surface. MGCO will be our first mission to Mars since the Viking spacecraft landed in 1976, and it will be crucial for solving some of the planet's remaining mysteries--the composition and extent of the polar ice reservoirs, its crustal chemical composition, and the origin of ice ages and catastrophic floods in its past. Mars is a very Earthlike planet in some ways, and the results from MGCO will also help us understand the weather and the climates of our own world.

The MGCO is a new approach to relatively lower cost planetary missions. It was the highest priority of a series of missions referred to as "Planetary Observers" by the Solar System Exploration Committee in their recommendation for a planetary core program. It will use a modified Earth-orbital spacecraft, and will have a very tightly focused science objective to perform geochemical, geophysical, and climatological mapping of the planet over a period of two years. If approved, in FY 1985 we plan to initiate procurement of the spacecraft bus and begin development of the most critical science instruments for the mission.

Galileo

The Galileo mission will conduct a comprehensive exploration of the planet Jupiter, its atmosphere, magnetosphere, and satellites through the use of both remote sensing by an orbiter and *in situ* measurements by an atmospheric probe. The scientific objectives of this mission are based on the recommendations by the National Academy of Sciences to provide continuity, balance, and orderly progression of the exploration of the solar system. The FY 1985 request for Galileo development is $56.1 million.

Development activities on the Galileo mission continue toward the planned 1986 launch on a Shuttle/Centaur. During late 1983, the Federal Republic of Germany (FRG) delivered the retropropulsion module that will be used to insert the spacecraft into orbit around Jupiter when it reaches the giant planet in 1988. We have completed the initial integration tests on both the atmospheric Probe and the Orbiter. We are, however, somewhat concerned about potential radiation problems which may be more serious than previously believed. We are currently studying this problem and plan to make a decision within the next few months as to the exact nature of the radiation shielding to be undertaken. The parachute system for the

Probe has been successfully tested. In FY 1985 integration of the orbiter and probe will be completed, and testing of the integrated system will be conducted. In addition, the mission software and ground systems will be completed leading to the spacecraft delivery to the Kennedy Space Center in early 1986.

International Solar Polar Mission

In FY 1985, we are requesting $9.0 million for the International Solar Polar Mission (ISPM), a joint NASA and European Space Agency (ESA) program. ESA will provide the spacecraft and some scientific instrumentation, and the U.S. will provide the remaining instrumentation, the launch, tracking support, and the radioactive thermoelectric power generators. The mission is designed to obtain the first view of the solar system from outside the plane in which the planets orbit the Sun. ISPM will allow us to study the relationship between the Sun and its magnetic field and particle emissions as a function of solar latitude to provide a better understanding of solar activity on the Earth's weather and climate.

In FY 1984, partial disassembly of the tested spacecraft will be completed and the spacecraft will be placed in storage until the start of launch preparations. FY 1985 funding will support U.S. principal investigators in mission planning, retrofitting of U.S. instruments with the ESA spacecraft prior to shipment to the Kennedy Space Center in late 1985, and ground system development activities. ISPM will be launched in 1986 on the Shuttle/Centaur Upper Stage combination.

Venus Radar Mapper

The Venus Radar Mapper (VRM), which was initiated in FY 1984, will provide a global map of the cloud shrouded surface of Venus. The VRM, using a synthetic aperture radar, will achieve a resolution sufficient to address fundamental questions regarding the origin and evolution of the planet. Data acquired will be analyzed so that the evolutionary history of Venus can be compared with the Earth's. The contracts for the Synthetic Aperture Radar and the VRM spacecraft were negotiated in 1983; the contract on the Synthetic Aperture Radar has been signed, and we expect to sign the spacecraft contract shortly. In FY 1985, we are requesting $92.5 million for VRM to support completion of the preliminary design reviews for the spacecraft and radar systems, for initiation of the fabrication of the subsystems, development of mission software, and for completion of the radar development test model. VRM is scheduled for launch in 1988 by the Shuttle/ Centaur Upper Stage on a direct trajectory to Venus.

Current Operational Planetary Spacecraft

The operational spacecraft include the Voyagers, the Pioneer Venus Orbiter and Pioneers 6-11. The FY 1985 funding request will support mission operations and analysis of data from these missions.

The Voyager spacecraft are continuing through the outer solar system, and Voyager 2 will encounter the planet Uranus in January

1986 and go on to encounter Neptune in 1989. During FY 1985 we will increase our test and training reviews in preparation for a full-scale rehearsal for this encounter. Funding is also required for developing new software to permit data compression for the encounter communications, thus increasing the yield of scientific information and taking full advantage of the Deep Space Network capability to array multiple antennas. This rendezvous with Uranus will be the first time that such data compression techniques have been used in a planetary encounter. Voyager 1 is now approaching the orbit of Uranus on its way out of the solar system, and it is continuing to provide data on the interplanetary medium. Analysis of the data obtained by the Voyagers' earlier encounters with Jupiter and Saturn will also continue in FY 1985.

The Pioneer 10 and 11 spacecraft are continuing to explore the outer solar system. Last June, Pioneer 10 became the first artifact to leave the solar system, and it is now entering that unexplored region where the Sun's magnetic field disappears into true interstellar space. Pioneers 6-9, in orbits around the Sun, are expected to operate until about 1988, collecting information on the interplanetary magnetic field and the solar wind, and in 1985-1986 they will make measurements in the vicinity of Halley's Comet. The Pioneer Venus Orbiter continues to orbit around Venus, collecting new data from formerly inaccessible regions of the planet's atmosphere. Last year, studies of the changes in the amount of atmospheric sulfur dioxide indicated that there might be active volcanism on the planet's surface, a possibility that we hope to explore more fully with the Venus Radar Mapper mission in a few years.

SPACE APPLICATIONS

ENVIRONMENTAL OBSERVATIONS

The physical characteristics of the Earth are the result of the interaction among many processes. The absorption of solar radiation and the subsequent transfer of the energy and momentum within the Earth's atmosphere and oceans produce the terrestrial climate in which we live. The convective flow in the Earth's interior, manifested by slow but unrelenting motions of large blocks of its surface, reshape the Earth continually. The motions in the dense metallic core produce the magnetic field which shields the Earth's surface from the solar wind and confines the Earth's magnetosphere. The study of the balance of physical and chemical processes on the Earth's surface and the near space environment provide the basis on which survival of living organisms on the land, in the oceans, and in the air can be understood.

The Environmental Observations Program strives to understand the large scale behavior of this complex environment which can be studied better from satellite measurements than from on the ground to determine how it responds to outside changes, and how its future behavior can be predicted. An ability to forecast accurately will have potential benefits ranging from predicting the weather and storms to providing the scientific basis for environmental and

energy-use policy decisions. In FY 1985, we are requesting $220.7 million for the Environmental Observations programs.

Upper Atmosphere Research Satellite (UARS)

The Earth's upper atmosphere is a critical and little-studied part of this complex environment. To help us in understanding this environment, we are requesting a FY 1985 new initiative--the Upper Atmosphere Research Satellite (UARS). The UARS program is a critical element in NASA's overall stratospheric research efforts. It will provide the first full data set on stratospheric composition and dynamics which will be required when very difficult decisions must be made, in the future, regarding production of chlorofluorocarbons. It will also contribute to an assessment of the impact of stratospheric changes on our climate and will provide the data needed for a full understanding of the stratosphere.

The Upper Atmosphere Research Satellite will carry a set of instruments which will make a comprehensive measurement of the state of the Earth's stratosphere. Detailed definition studies of the instruments have been completed, and design and development activities have begun. In FY 1985, design and development activities will be initiated on the UARS observatory. We are planning to launch the satellite in the fall of 1989.

Scatterometer

The FY 1985 budget request also includes funding to develop a Scatterometer Radar to be flown on the Navy Remote Ocean Sensing Satellite (N-ROSS). N-ROSS will acquire global ocean data for operational and research use by both the military and civil sectors. The scatterometer will provide accurate, global measurements of ocean surface winds which will be useful for both oceanography and meteorology, and in addition to satisfying Navy operational requirements, will permit the first global study of the influence of winds on ocean circulation, and provide feedback on the effects of the oceans on the atmosphere and provide improved marine forecasting. In FY 1985, design and development activities of the Scatterometer will be initiated, leading to a launch on the N-ROSS in 1988.

Earth Radiation Budget Experiment (ERBE)

The objective of the Earth Radiation Budget Experiment (ERBE) is to measure the temporal and spatial variations of the Earth's radiation budget to gain basic insight into the causes for climatic fluctuations. A detailed understanding of how this radiation is absorbed and reflected by the Earth's atmospheres and oceans is essential if we are to understand the mechanisms behind weather and climate. The Earth Radiation Budget Experiment (ERBE) will measure how the absorption and re-emission of solar energy are distributed over the Earth. The Earth Radiation Budget Satellite (ERBS) was completed in 1983 and the instruments were integrated with the Satellite. Environmental testing will be completed shortly and the system will be shipped to KSC for launch later this year.

The ERBE sensors will be flown on ERBS, NOAA-F and NOAA-G satellites. FY 1985 funding of $8.1 million will support the operation and analyses of data from ERBS and NOAA-F and analysis of data for updating the climate models.

Tethered Satellite System (TSS) Payload

In FY 1985, we are also requesting funding for Tethered Satellite System (TSS) Payloads. The TSS is a joint program with the Italian government. It will open new areas of scientific research not now possible because investigations can be conducted below the Space Shuttle's orbital altitude. The National Research Council of Italy will provide the satellite and NASA will provide the deployment mechanism and overall systems integration. A conducting tether can generate large amplitude hydromagnetic and electrodynamic waves to study space plasma phenomena. A payload, lowered below 180 kilometers, can study a region of the Earth's atmosphere on a global basis, which is presently only accessible by sporadic rocket flights, and can make high resolution crustal geomagnetic measurements. The FY 1985 budget request is required for development of instrumentation to be flown on the first TSS mission in 1986. This instrumentation is being designed both to gather scientific data and to test and demonstrate the Tethered Satellite System.

Extended Mission Operations

The FY 1985 funding request of $29.5 million will support mission operations and data analysis activities on the International Sun-Earth Explorer which has been renamed the International Cometary Explorer and will fly through the tail of Comet Giacobinni-Zinner in 1985; the Interplanetary Monitoring Platform and the Dynamic Explorer satellites. Preliminary activities will also begin in FY 1985 for extended operations support of the Active Magnetospheric Particle Tracer Explorer. Operations, processing, and validation of data from Nimbus and Solar Mesosphere Explorer (SME) satellites will be continued in FY 1985 as will activities to provide ground truth for a NASA-developed ozone instrument to be flown on a NOAA weather satellite. These operational satellites continue to produce extremely valuable data.

SOLID EARTH OBSERVATIONS

The objectives of the Solid Earth Observations program are to develop space observations and experimentation techniques to further the understanding of the global, physical, chemical and biological processes involving the land areas of the Earth and the interactions of the land areas with the oceans and atmosphere; to improve our ability to evaluate the composition and geometry of the Earth's mineral and energy resources; and to increase our understanding of the Earth, its interior structure and composition, its rotational dynamics, and mechanisms associated with the occurrence of earthquakes.

One of the important aspects of the Solid Earth Observations program is the research associated with understanding the physical relationship of electromagnetically sensed phenomena to the radiation emitted or reflected by various types of surface features of Earth, and the development of models to increase our understanding of global processes. The studies of the movement and deformation of the Earth's crust help us to understand the processes leading to earthquakes. Other studies improve our understanding of the formation of mineral deposits, contribute to long term weather and climate forecasting, and help us to better understand the Earth as a planet.

FY 1985 funding will continue support of the principal elements of the program, including the development of spaceborne and supporting ground systems; improved data processing and analysis techniques; Shuttle and aircraft support for sensor and technique development; and basic and applied research for identifying and analyzing the vegetated and geological features of the Earth.

The Solid Earth Observation activities, coupled with the Environmental Observation program comprises an integral part of the total Earth Sciences and Applications effort with emphasis on understanding the Earth as a planet, studying its dynamics, processes, habitability, and the solar-terrestrial environment.

LIFE SCIENCES

In FY 1985 we are requesting $63.3M to continue our multi-disciplinary Life Sciences program. This program provides a sound scientific, medical, and technical basis for safe and productive manned space flight, and advances our understanding of basic biological processes by using the unique capabilities of the space program. Our Life Sciences program is a key element in developing our capability to sustain a permanent manned presence in space and using the space environment to study living systems.

Finding better ways of dealing with the Space Adaptation Syndrome (SAS) remains an issue of paramount importance. This syndrome which is characterized by nausea appearing during the first two or three days of weightlessness is being studied in several ways. Investigators are unravelling the underlying neural pathways and physiological mechanisms by which the living organism responds to motion stimuli and how it orients itself with respect to its environment. An intensive search is underway for more effective drugs to deal with SAS as well as for techniques that will permit the astronaut to suppress motion sickness symptoms in flight.

For Shuttle flights, as has been the case for earlier space missions, proper cardiovascular functions must be ensured. Without adequate protective measures we observe elevated heart rates, low blood pressure and other changes following the reentry phase of the flight. We continue to seek more effective and less cumbersome countermeasures by conducting research both in simulated and in actual space flight. More sophisticated non-invasive diagnostic

equipment is being used to measure the circulatory changes that occur, and various treatments are being devised to mitigate them.

Studies are being pursued to understand more about why bones demineralize in space as well as during long periods of inactivity on the ground. We are testing drugs that may stem these bone losses not only in astronauts but also in our elderly population. Ground-based and inflight research is also in progress to define more clearly the changes induced by spaceflight on fluids, electrolytes and hormones, on muscles and on the ability of the body to cope with infections and environmental stresses. Most importantly studies are directed toward improving the habitability of space vehicles and toward ensuring that the humans who occupy those vehicles can be as productive as possible. Attention is paid toward defining more precisely specifications for atmosphere, noise, vibration, and nutrition. Preliminary studies are also underway to monitor health status more reliably and to deal with medical emergencies that might arise in space.

Unravelling the fundamental responses of living organisms to gravity is not only of great importance to space medicine and to the development of space-borne ecological systems, but it is of profound scientific interest as well. Experiments are being done on the ground and inflight to characterize and compare these responses. We are particularly interested in the structures by which organisms sense gravity and in the effects that gravity has on the development, maturation and aging of animals. The role of gravity in biochemical and cellular processes is also being closely scrutinized.

To better understand the effects of weightlessness on humans and other living organisms, we will continue the development of a space-borne biomedical laboratory to be flown on the Shuttle/Spacelab. At the present time, we are supporting approximately 25 principal investigators for the development of major flight experiments. The Spacelab 3 Life Sciences flight hardware has already been delivered to the Kennedy Space Center for integration into the Spacelab module in preparation for launch later this year. Spaclab 4, scheduled for launch in late 1985, is the first dedicated Life Sciences Spacelab mission; it will represent a significant step forward in understanding human physiological changes resulting from spaceflight. This mission will emphasize those medical issues such as cardiovascular deconditioning and vestibular disturbances.

SHUTTLE SPACELAB PAYLOADS

For the past 2-1/2 years, we have been learning how to use the unique capabilities offered by the Shuttle/Spacelab for conducting scientific and applications research. During this time we have flown two pallet missions, several investigations on the Shuttle mid-deck, and the first dedicated Spacelab mission, Spacelab 1. We have established our Spacelab Ground Processing Operations support facilities at the Kennedy Space Center (KSC), and it was used for the first time when we integrated Spacelab 1. The Spacelab program

spans an impressive spectrum of research disciplines as the number of flights per year significantly increases.

Our splendid success with Spacelab 1 provides an important reference for the future success of the Space Station. Our Shuttle Payloads Program is part of an evolutionary process--we have progressed from attached payloads, which proved the value of the Shuttle for science and applications requirements to the shirt-sleeve environment of the Spacelab. The next logical step in this evolutionary process is the establishment of a permanent presence in space, and our Spacelab program serves as an important data point for demonstrating the utility of space-based laboratories for the advancement of space science and applications and the value of international cooperation in achieving these goals.

On the seventh Shuttle flight, in June 1983, OSTA-2, a cooperative materials processing mission with the Federal Republic of Germany, was flown. The U.S. portion of the project was the Materials Experiment Assembly (MEA) which contained three sounding-rocket class furnaces. The MEA is now being prepared for reflight in late 1984. Germany's contribution was three self-contained experiments flown in cannisters alongside the MEA to study fluid dynamics, transport phenomena and metallurgy.

We continue to make substantial progress on other missions as well. In June 1984, the OAST-1 and the Large Format Camera payloads will be flown. The OAST-1 payload is a technology demonstration mission for large deployable structures and the Large Format Camera will acquire high resolution mapping quality photographs with black and white, color, and color infrared film.

The upgraded Shuttle Imaging Radar (SIR-B) is scheduled for flight in August 1984, along with the reflight of the Large Format Camera, and several other instruments to acquire imagery for a broad range of investigations in geology, agriculture, hydrology, and ocean ice. The antenna for SIR-B is articulated to permit evaluation of backscatter phenomena at depression angles from 15 to 70 degrees.

Spacelab 3 will employ the Spacelab module as a manned laboratory for performing experiments in the disciplines of materials processing, life sciences, and technology. The launch is scheduled for November 1984. The Very Wide Field Camera which recently flew on Spacelab 1 will be reflown on the Spacelab 3 mission.

Spacelab 2, planned to be launched in early 1985, will carry out scientific investigations in the areas of solar physics, high energy astrophysics, infrared astronomy, plasma physics, life sciences, and space technology. Thirteen instruments, two of which are from the United Kingdom, will be flown. The mission, currently scheduled for an early 1985 launch, will be a verification flight of the all-pallet/Igloo Spacelab configuration with the ESA-developed Instrument Pointing System (IPS) flying for the first time.

The ASTRO mission, which consists of three ultraviolet telescopes, represents our first major step in a shuttle-based ultraviolet astronomy program. These instruments will observe various astronomical objects, such as intrinsically polarized stars, quasars, active nuclei of galaxies, and globular clusters. The first flight of ASTRO is scheduled for March 1986, to coincide with the European, Soviet, and Japanese spacecraft encounters with Halley's comet. Plans have been made to observe the comet in ultraviolet wavelengths using these three telescopes. Reflights of ASTRO are scheduled for late 1986 and mid 1987.

The Solar Optical Telescope (SOT) is planned to be carried on several Spacelab flights in the early 1990's for ultra-high resolution studies of the Sun at near infrared, visible, and ultraviolet wavelengths. The SOT will have a 1.2-meter aperture. Instruments for the first flight were selected in 1981. In FY 1985, we plan to continue design and definition studies leading to a launch in 1991.

MATERIALS PROCESSING IN SPACE

We are in the process of revamping and revitalizing our Materials Processing in Space (MPS) Program. Recognizing the inherent potential for commercial applications, and the operationally available Space Shuttle which is able to carry heavy payloads for long duration in 0-g, we have moved to expand the MPS charter and strengthen its management.

The Materials Processing in Space Division within Space Science and Applications has been renamed the Microgravity Science and Applications Division and will perform research in areas where microgravity plays a significant role in the basic process. Certainly, this is true of materials research, but it is equally true of basic physical and chemical phenomena as well. The Division has recently been assigned the development into flight experimentation of the Physics and Chemistry Experiments (PACE) formerly sponsored by the Office of Aeronautics and Space Technology, as the technology has been carried to the point where development hardware is the next logical step. These experiments (which require microgravity) have now been incorporated into the basic program. Investigations will be conducted in areas such as critical point phenomena, combustion, and relativity.

The FY 1985 budget request of $23.0 million will continue ground-based research and analysis in the areas of metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion and fluid dynamics, and transport phenomena. Research will be continued to define the role of gravity driven influences in generic processing methods. The experimental capabilities of the drop tubes, drop towers and aircraft will be maintained to support all scientific and commercial participants in the program. Support will continue for commercialization activities such as joint endeavor and technical exchange agreements, and the outreach program, which provides technical publications, workshops, visits to

NASA centers, and experiment accommodation studies to interested industries. Support for the one or more universities selected as a center for bioprocessing research will be maintained. Efforts to establish a NASA-industry-university center for research and as a Space Station test bed at the Lewis Research Center will continue. Definition studies will be continued for experiment candidates in both materials science and the Physics and Chemistry Experiments area. The development of new flight apparatus, refurbishment of previously flown apparatus, and the upgrading of available hardware will be supported in order to refly present experimenters or to accommodate new experimenters.

The frequency of experiments using the Shuttle middeck and cargo bay substantially increased last year and the investigations showed the utility of simple experiments for focusing on those areas where microgravity effects may be significant. For example, the OSTA-2 payload was flown in the cargo bay on STS-7. This was a cooperative mission between West Germany and the United States to fly simple materials processing experiments. The West German experiments were contained in Get Away Special cannisters and investigated formation of second phase droplets in immiscible gallium mercury mixtures as well as the directional solidification of cesium chloride. The United States' experiments were flown on the Materials Experiments Assembly, an autonomous battery-powered system which can carry and operate sounding rocket class hardware. This mission consisted of an isothermal furnace, a gradient furnace, and an acoustic levitation furnace. Experiments were also flown in the Shuttle middeck last year, and the study of the production of monodisperse latex spheres in microgravity was continued on STS-7. As a result of that success, the National Bureau of Standards has certified these spheres as standard calibration sources and requested NASA to continue work in this area. Additional middeck experiments were conducted using the McDonnell Douglas (MDAC) Continuous Flow Electrophoresis System (CFES). MDAC has continued to investigate the separation of proprietary tissue cultures in space and are sufficiently encouraged by these results to proceed with their remaining middeck and cargo bay experiments scheduled under the Joint Endeavor Agreement with NASA.

This year saw the final checkout and assembly of the Fluid Experiment System/Vapor Crystal Growth (FES/VCG), which will grow and monitor triglycerine sulfate crystals from solution and mercuric iodide from vapor. The FES/VCG was delivered to the Kennedy Space Center for installation into Spacelab 3, a major portion of which is dedicated to microgravity experiments.

We have also been developing areas of potential commercial interest. We will continue our work with Microgravity Research Associates on Gallium Arsenide as well as the research with John Deere, Minneapolis Honeywell, and INCO. New work with the 3-M Corporation, Children's Hospital of Boston, and Alcoa has been started and discussions with several other firms are underway. NASA is actively working to insure that access to space is readily available to US commercial organizations.

COMMUNICATIONS

In FY 1985 we are requesting $20.6 million for Communications. This funding continues to support the development of component and device technology required by NASA, other government agencies, and United States industry for advanced communications satellite systems. It also supports the Search and Rescue Program, technical consultation, and experiment coordination and operations.

The Advanced Communications Technology Satellite (ACTS) Program is designed to develop advanced communications switching, processing, and antenna technologies, and to regain U.S. technological leadership in this important field. Originally, we had planned to fly the ACTS satellite to provide a flight test. However, in view of private sector activity in commercial systems, we have restructured our plans to continue the ACTS program as a technology development effort. We plan to develop all the technology needed for the satellite switched time-division-multiple-access (TDMA) and base band processor subsystems and to build these into a test bed. We will subject these systems to extensive ground testing and simulation. This program is expected to pay dividends in developing the technology needed for the Advanced Communications satellites of the 1990's and to keep American industry in a leadership position.

The budget request will continue activity in the Advanced communications research and technology areas. We have recently completed planning for an international cooperative Mobile satellite mission, and plan to continue development of critical component technologies related to all areas of space communications technology.

Communications Technical Consultation and Support Studies

This effort continues to provide for studies of radio interference, mobile communications, propagation, and special systems studies required for the growth of existing satellite services. We continue to support the Department of State, the Federal Communications Commission, and the National Telecommunications and Information Administration, in preparing for three World Administrative Radio Conferences scheduled for 1985-1988 on geostationary orbit planning for all space services.

Experiment coordination and mission support in Communications provides continued support of the Applications Technology Satellites, (ATS-1, -3, and -5), and the appropriate documentation and archiving of nearly 400 user experiments and demonstrations that have been conducted.

Search and Rescue Satellite System

During the past year, the number of satellites equipped to support search and rescue grew to three, including the first U.S. satellite, NOAA-8. Ten ground stations in the United States, Canada, France, the Soviet Union, Norway, and the United Kingdom are now operational, and the use of the system to assist actual search

and rescue operations on a regular basis is now a reality. Discussions are underway with a number of other countries concerning potential participation in the project. To date, the system is credited with saving 150 lives. FY 1985 funding will support improvements to the ground stations and research and development activities required to permit the most effective operational system for the 1990's. Development of distress transmitters will be continued, and experiments using geosynchronous spacecraft to relay signals to complement polar satellites will be conducted.

Communications Research and Analysis

There is clearly a demonstrated national need for effective long-range communications planning and for the development of spectrally efficient satellite communications technology which will mitigate the effect of foreign competition and maintain a continued United States preeminence. Funding for FY 1985 will provide for continued development of high-risk communications technology, including Large Scale Integration processor and modulator/demodulator technology for more efficient utilization of the microwave spectrum. The Proof-of-Concept components delivered to NASA will be integrated and tested to ascertain quality of performance. High efficiency and low cost Traveling Wave Tube transmitter circuits and techniques will be developed in addition to solid state devices and combiners for solid state transmitters. These technologies will be developed for space and ground terminal applications.

SUPPORTING PROGRAMS

Our suborbital and research and analysis programs provide the foundation for our flight programs. Research and Analysis activities fall into five general areas: extended data analysis, laboratory investigations, complimentary ground-based observations, theoretical studies, and instrument definition and development. Past missions have accumulated a wealth of data on a wide range of natural phenomena; however, the data analysis during the operational lifetime of a mission cannot fully extract all the knowledge to be gained from the data. Extended data analysis continues to capitalize on the valuable data sets after missions are formally complete. Ground-based observations provide the complementary and ground-truth data needed to fully interpret the space observations while laboratory investigations provide additional information on the physical process being observed. Theoretical studies provide a broad perspective on the observed phenomena.

Our future missions build on the base provided by past missions and supporting programs. Theoretical studies lead to new theories that must be tested and suggest new observations to test old theories. Instrument definition and development, which provides the technological base for our research missions, is a multifaceted activity which is carried out in the laboratory, on suborbital flights and on the Shuttle. In addition, we maintain a vigorous program of medical studies to protect the health of humans in space and to enhance their productivity. These supporting programs provide a significant fraction of the basic research support to the

university, government, and industrial scientific researchers who make up the heart of the space science and applications program.

Suborbital Research Programs

In the last fiscal year, NASA launched 44 balloons to support upper atmospheric science, astrophysical research, and solar physics. One particularly significant event was the Balloon Intercomparison Campaign in which three balloons were launched at the same time to collect correlated data on the properties of the upper atmosphere. In 1984, we expect to launch approximately 60 balloon-borne missions from locations in the continental United States, Hawaii, and Alaska. In FY 1985, the balloon program will continue at approximately the same level.

There were also 53 sounding rocket missions launched the past fiscal year to support space plasma physics, astrophysical and solar science, upper atmospheric research, planetary science, and materials processing science. In addition to launches from the continental United States, Alaska, and Canada, there was a very successful mobile launch campaign for studying the behavior of plasmas in the equatorial region above Punta Lobos, Peru. In FY 1984, NASA will support approximately 50 missions from ranges in the continental United States, Alaska, Canada, and Norway. In FY 1985, the sounding rocket program will continue at approximately the same level.

To take advantage of the capabilities of the Space Shuttle, we have undertaken an effort to convert some of our sounding rocket payloads to Space Shuttle payloads in a program called Spartan. Spartan missions will be deployed, allowed to operate autonomously for up to 40 hours, and retrieved by the orbiter. The first mission, Spartan 1 will carry a highly collimated proportional counter to investigate hard X-rays from a supernova remnant and clusters of galaxies, and is scheduled for launch in the summer of 1984. The increase in observing time from the few minutes typically available in a sounding rocket flight make Spartan an especially attractive means for conducting scientific investigations in space with experimental instrumentation. The Spartan missions represent a new and novel use of the Shuttle and provide an excellent, cost-effective resource for acquiring scientific data on a routine basis.

The Kuiper Airborne Observatory with its 91-centimeter telescope continues to perform valuable scientific observations at the nominal rate of 80 flights per year. This past year, this observatory was taken on an expedition to Australia to make far infrared observations of the center of our own galaxy. In FY 1985, flights will be continued for exploration in the star-forming region, and data gathered by IRAS will be used extensively to determine targets of observation.

Research and Analysis

The Research and Analysis program is consciously and coherently structured to support major improvements in our understanding of the results from past and current missions. In Solar Physics,

development continues on optical systems that could revolutionize the way we make telescopes for soft X-ray observations. Meanwhile, in High Energy Astrophysics, we are supporting efforts to develop high resolution spectroscopy of cosmic X-ray and gamma-ray sources. Besides investigations using new instruments for infrared and ultraviolet astronomy, our Astronomy and Relativity program investigates the effects of Einstein's general theory of relativity.

Our exploration missions through the solar system are supported by an active program of ground-based research and observations. This program provides a scientific base for mission planning, operations, and data interpretation and also is an essential source of scientific data that are not obtainable by spacecraft. A major scientific discovery last year was the recognition of a planetary (not asteroidal) origin for several meteorites collected in the Antarctic. A small (one-ounce) specimen collected in 1982 was definitely a piece of the Moon, while others may be volcanic lavas blasted off the surface of the planet Mars by great meteorite impacts in the distant past. Meteorite studies last year also provided evidence for the presence of interstellar carbon particles in carbon-rich meteorites.

FY 1985 funding is required to continue research efforts in planetary science, instrument definition, Mars data analysis and development of required technology to undertake future missions. In addition, we will also continue support of the U.S. co-investigators involved in the European Space Agency's Giotto mission and support for the astronomical study of Halley's Comet, the International Halley Watch as well as continued operation of both the Infrared Telescope Facility and the Lunar Curatorial Facility.

Space Plasma Physics

Space plasma physics research is a broadly structured effort to enhance our understanding of the characteristics and behavior of plasmas in the solar corona, the interplanetary medium and in the vicinity of the Earth and other planets. The major thrust of the program is directed at studies of the near Earth environment, from the flow of the solar wind past the magnetosphere, to manifestations of variations of the plasma environment detectable near the surface of the Earth. This field of research is one of relative maturity, with emphasis on multipoint and time sequence measurements and active perturbation experiments. For example, there are currently three spacecraft systems, the Interplanetary Monitoring Platform, the International Sun-Earth Explorer, and the Dynamics Explorers taking such measurements. In 1984, the Active Magnetospheric Particle Tracer Explorer (AMPTE) will be releasing tracer plasmas and making space and time measurements. The Solar Terrestrial Theory program continues to provide a strong basis for all programs in both solar physics and space plasma physics.

In FY 1985, we will continue our program of suborbital investigations, theoretical and laboratory studies, and analysis of existing data from spacecraft. The Solar Terrestrial Theory program will be continued to research the full range of phenomena in this

portion of the environment, and steps will be taken to build a comprehensive and quantitative aggregate model of the solar terrestrial interaction.

Weather, Climate and Severe Storms

NASA Climate Research seeks to develop a space capability for global observations of parameters which contribute to our understanding of the processes which influence climate and its predictability. Recent accomplishments and future thrusts are in the areas of solar irradiance monitoring, Earth radiation budget monitoring and analysis, the distribution and effect of cloud systems and of stratospheric aerosols on the radiation budget, and studies of selected processes which relate to monitoring of climate change. The past year's activities have included extensive flight surveys to monitor the effect of the El Chichon volcanic aerosols on the climate and the successful launch and initiation of the International Satellite Cloud Climatology Project (ISCCP).

The goal of NASA Global Scale and Mesoscale Atmospheric Research Programs is to develop an improved capability for observing the Earth's atmosphere from space and to apply these observations to improving predictions of atmospheric processes. Funding requested for FY 1985 will support aircraft flights to study the details of flows around thunderstorms and fronts, comparison of models, studies of atmospheric scale interactions, and development of techniques to display model outputs in three dimensions. Archiving of global International Satellite Cloud Climatology project data, analysis of ERBE data, and ground-based and rocket flight support for solar irradiance monitoring, as well as technology development of active temperature, pressure, and moisture sounders and basic Lidar technology development will also be continued in FY 1985.

Oceanic Processes

Oceanic Processes Research develops spaceborne observing techniques and applies them to advancing our understanding of the fundamental behavior of the oceans and to assisting users with the implementation of operational systems. Among the users are federal agencies (Defense, NOAA, NSF) and the governments of foreign countries (Canada, Europe, Japan).

FY 1985 funding will be used to continue analysis of NIMBUS-7 and SEASAT data. Work will also continue on the pilot ocean data system with major thrusts focused on planning a data processing and archival facility from the N-ROSS Scatterometer and the future Ocean Topography Experiment (TOPEX). Funds will also continue the definition of operational observational capabilities using existing technology to advance our understanding of fundamental ocean behavior.

Upper Atmospheric Research

Since 1976, we have carried out a program of Upper Atmospheric Research designed to improve our understanding of the stratosphere

to produce scientific assessments of the probable threat to the ozone layer from chloroflourocarbons and other residual substances introduced into the atmosphere by human activity. Laboratory measurements are made of the rates of chemical reactions involving stratospheric constituents. This information is included in predictive models and is used in the design of new measurement techniques. Observations are made from a variety of suborbital platforms: aircraft, balloons, and rockets. Satellite measurements provide the global data needed to determine the distribution of ozone and other chemicals, and the circulation of the upper atmosphere, and we are developing models to quantify our understanding of these processes and to make assessments of the ozone layer response to external changes. FY 1985 funding will support model calculations and interpretation of satellite data, the development of more realistic two and three dimensional models, and analysis of global data sets from past and current satellites to help understand largescale processes at work in the upper atmosphere.

Tropospheric Air Quality Program

The Tropospheric Air Quality Program seeks to improve the understanding of global tropospheric chemistry and dynamics. Key elements of the program include understanding of the global troposphere as a source and sink for upper atmospheric trace gases and the buildup of infrared active gases in the troposphere with its potential impact on earth's dynamics in biogeochemical cycles. Current activities are aimed at the identification of principal processes and key species in troposheric chemistry and at the improvement in the capability to measure atmospheric constituents. A series of field experiments will be conducted in FY 1985 to evaluate these new measurement techniques.

Land Processes

The Land Processes Program develops remote sensing technology and applies it to the study of the Earth's land surface. Research is conducted within specific disciplinary fields to determine the various types of ecological, geological, and hydrological information that can potentially be inferred from remotely sensed data. In FY 1985 and subsequent years, the Land Processes Program will be focused toward research involving the biosphere and various biospheric activities.

During FY 1985, the research and analysis disciplines will make use of the data from the infusion of Landsat-4 Thematic Mapper data. New radar data from the SIR-B will also be available. The research and analysis program will focus on the analysis of these new data, improved understanding of long-term land processes, and some technique sets. Fundamental remote sensing science research will be continued in scene radiation and atmospheric effects, and pattern recognition and image analysis. Advanced mission studies will be continued with emphasis on Shuttle-borne sensor feasibility studies and Space Station payload studies.

Geodynamics

Studies of the solid Earth using laser ranging to satellites and the moon and microwave interferometry involving signals from astronomical radio sources are providing new and intriguing scientific results. Equally important is the rapidly expanding international effort in cooperative studies of global geodynamics.

We now have, for the first time, direct measurements of the present-day relative rates of motion of six of the dozen or so major tectonic plates which comprise the Earth's outer shell. These movements, which generally amount to a few centimeters per year, are responsible for the earthquakes which occur at plate boundaries.

We have also learned that the motions of the Earth as a rotating body are closely coupled with mass movements in the Earth's atmosphere. Changes in the length of day amounting to a few thousandths of a second per year are due to changes in the atmosphere's angular momentum. Similarly, some 90% of the motion of the Earth around its axis of rotation is due to mass redistribution within the atmosphere. Preliminary data indicate that the El Niño, which drastically changed our weather structure last year, is correlated with a slowing of the Earth's rotation.

Life Sciences

The Life Sciences Biological Research Program supports basic research addressing fundamental questions about living systems which can best be answered by access to the space environment or through capabilities developed as a result of space exploration. Exobiology Research deals with understanding the origin, evolution, and distribution of life and life-related molecules on Earth and throughout the universe. The recent discovery of the basic components of genetic material in meteorites demonstrates the potential for the occurrence of life-related organic chemistry elsewhere in the universe. The Biospheric Research program studies life as a modulating force which governs the cycling of materials and energy throughout the biosphere and its influence on global scale processes. Research in FY 1985 will be focused on measuring ground biogenic gas fluxes of important atmospheric constituents and correlation with aircraft measurements and regional biomass estimates.

Progress is also being made in the technology underlying advanced life support and extravehicular activity systems. This technology deals with the recycling of water, the regenerating of air and the management of food and waste onboard spacecraft that have long operating lifetimes. The FY 1985 request will be used to continue collection of information in zero-gravity on each Shuttle flight, including inflight clinical testing for health care, and evaluation of medical data related to space flight.

FUTURE PROGRAMS

So far, I have described to you programs and activities that are currently underway or are proposed for initiation in FY 1985. The Office of Space Science and Applications also has an extensive planning activity which looks toward future opportunities to build upon previous results or to initiate new lines of research. I would like to conclude my statement by indicating a few of the near-term possibilities. It should be noted that in doing our planning, we work extensively with the scientific community and that each possible new initiative has emerged as a result of thorough debate and exhaustive scrutiny by a significant segment of the country's leading scientists.

Advanced X-ray Astrophysics Facility

Nearly every object in the universe, from planets to quasars, emits X-rays or has sources of X-rays embedded within it that dramatically alters our understanding of the object. As a result, the Astronomy Survey Committee of the National Academy of Sciences made the Advanced X-ray Astrophysics Facility (AXAF) its highest priority for a new major observatory in the 1980's.

AXAF will be a powerful observatory dedicated to the investigation of almost every astronomical object. It will be an imaging telescope with a new generation of grazing-incidence mirrors that will double the energy range over which it operates and give an order of magnitude better angular resolution than any other X-ray telescopes flown or now planned. In FY 1985, we will continue feasibility and definition studies on AXAF.

Shuttle Infrared Telescope Facility

The true richness and beauty of the infrared sky have been revealed for the first time by IRAS and underscores the importance of the Shuttle Infrared Telescope Facility (SIRTF), a true observatory carrying a variety of focal plane instruments and capable of extensive observations of individual targets. SIRTF will have a 1-meter class cryogenically cooled optical system and a new generation of infrared detectors that will make it 100 to 1000 times more sensitive than IRAS. Good sensitivity is needed for a survey, but much higher sensitivity is needed to understand the sources discovered. Because of the technical success with IRAS, we are studying the possibility of making SIRTF a "free flyer," either on a dedicated spacecraft or by placing it on a platform, co-orbited with and serviced by the manned Space Station. We have released the Announcement of Opportunity for scientific instruments to go in the focal plane of SIRTF, and many excellent instruments have been proposed.

Solar System Exploration

The future of solar system exploration has been the subject of a thorough and detailed study by the Solar System Exploration Committee (SSEC). Last year, the Committee completed its

recommendations for an essential Core Program for scientifically valuable, cost-effective planetary exploration. In FY 1985 we are requesting funds to initiate the first of SSEC's recommendations, the Mars Geoscience Climatology Orbiter which was the highest priority mission recommended by the Solar System Exploration Committee. At the same time, we will continue to study possible additional future moderate cost Planetary missions, including a Lunar Geochemical Orbiter, a Venus Atmospheric Probe, and a Mars Surface Probe. We will also be studying the Mariner Mark II series of missions which will enable us to send valuable scientific missions to the outer planets such as Saturn and the as-yet-unvisited small bodies of the solar system: asteroids and comets. During FY 1985, the SSEC will complete its studies of more ambitious activities that cannot be achieved within the core program--more sophisticated, high quality science missions to both inner and outer planets, missions to lay the groundwork for the eventual utilization of near-Earth resources, and the role of the Space Station in supporting such missions.

Life Sciences

Future research in Life Sciences will strive primarily to improve human productivity in space by enhancing the habitability of space vehicles by better understanding the interaction between humans, their environment, and the machines that can be placed at their disposal.

Starting with Spacelab 4 in late 1985, Life Sciences flight activities will include dedicated Spacelab missions every 24 to 30 months and shared Spacelab missions between these major efforts. We are also starting to evaluate the use of satellites to be launched and retrieved, or revisited, by STS for use by Life Sciences investigators.

Ocean Topography Experiment (TOPEX)

The objective of the Ocean Topography Experiment (TOPEX) is to provide a basis for improving our understanding of the general circulation of the world's oceans. Such information is needed to better understand how the atmosphere drives the circulation of the oceans, how the oceans in turn influence the atmosphere, and ultimately, the role of the oceans in climate. TOPEX will use radar altimetry to measure the surface topography of the oceans for several years, and when combined with appropriate observations *in situ*, the resulting topographic data will enable us to determine for the first time the three-dimensional structure of the ocean currents. While TOPEX will be principally a NASA program, the Navy, NOAA, and DMA are each considering significant contributions to the program. In FY 1985, work on the pilot ocean data system will focus on planning a data processing and archival facility from the Scatterometer to be flown on the Navy's N-ROSS mission as well as the future TOPEX mission. Additionally, because France has a significant interest in observing the oceans with altimetry technique, a study of a joint mission is being conducted. In this joint effort with the French Space Agency (CNES), we will consider a

possible launch of TOPEX with the Ariane launch vehicle in exchange for scientific cooperation and the flight of some French instrumentation. A U.S. only mission involving launch of TOPEX by the Space Shuttle is also being studied. TOPEX could be launched as early as 1989.

International Solar-Terrestrial Physics (ISTP) Mission

In September 1983, NASA hosted a trilateral science meeting of ESA, the Japanese Institute of Space and Aeronautical Sciences, (ISAS), and NASA representatives who recommended that the three agencies pool their resources to create the spaceflight segment of an International Solar-Terrestrial Physics Program (ISTP) which was previously called Origin of Plasmas in the Earth's Neighborhood (OPEN). From this meeting emerged a promising future effort in solar-terrestrial physics (ISTP).

Under the ISTP plan NASA would provide three spacecraft with instruments from the international science community as selected under the Origins of Plasmas in the Earth's Neighborhood (OPEN) Program. These spacecraft are called WIND, EQUATOR, and POLAR to designate the region of principal measurements--the solar wind, the equatorial region and the polar region. In addition, NASA would provide some instrumentation to the ISAS GEOTAIL spacecraft which investigates the middle and deep magnetic tail regions of the Earth. ESA is studying two missions as cooperative programs with NASA which can contribute to the ISTP Program: the Solar Heliospheric Observatory (SOHO)--meeting some of the objectives of the NASA Solar Coronal Explorer and Solar Dynamics Observatory--for solar coronal dynamics and solar seismology; and CLUSTER, providing mesoscale measurements of plasma turbulence--similar to the NASA Plasma Turbulence Explorer.

During FY 1985, negotiations will continue on this potential future program and definition studies for potential missions will be conducted.

Geopotential Research Mission (GRM)

Understanding the Earth's gravity and magnetic fields is assuming increased importance in the resolution of fundamental scientific questions relating to the solid Earth and physical interactions within the total Earth system. Understanding these fields is also important to discerning the distribution of materials within the crust and to practical application involving navigation and control of aircraft, missiles, and spacecraft.

The Geopotential Research Mission (GRM) will be designed to achieve the measurement accuracies and spatial resolutions needed for this research. The mission will have two spacecraft in the same orbit separated by several hundred kilometers. A precise, satellite-to-satellite microwave tracking system will measure the change in velocities between the two spacecraft caused by the

gravity field. The magnetic field measurements will be obtained by scalar and vector field magnetometers mounted on the boom on one spacecraft.

Gravity Probe-B (GP-B)

The potential future mission Gravity Probe-B (GP-B) would place extremely precise gyroscopes in polar orbit to see if the spin of the Earth will change the pointing direction of the gyroscopes. This mission would provide a new test of Einstein's General Theory of Relativity. According to general relativity, the rotation of the Earth drags space around with it, producing a small extra motion of gyroscopes which is not predicted by Newtonian physics. The technology to sense this effect has been developed in the last 22 years, and study and demonstration of the technology for this mission will continue this year.

Earth System Sciences

NASA has formed an Earth System Sciences Committee (ESSC) under the NASA Advisory Council to study the needs and opportunities for a comprehensive program for NASA in all the Earth sciences involving the atmosphere, hydrosphere, lithosphere, and biosphere--indeed, to study the Earth as a system. The ESSC has been asked to develop a comprehensive program and plan for NASA in Earth system sciences.

Space Station

In anticipation of a future Space Station, we are actively studying possible space science and applications utilization of both manned and unmanned elements of the proposed Space Station program. We have established close links with the Space Station Task Force and have sought the advice of the Space Science and Applications Boards to ensure that Space Station planning appropriately considers space science and applications requirements. We will also study the feasibility of using the laboratory module of the manned Space Station and associated unmanned platforms to be serviced by the Space Station for science and applications missions. We are particularly interested in the Space Station co-orbiting platform for astronomical missions and the polar-orbiting platform for Earth observation missions. We will continue to be closely involved in the design and definition of the Space Station program.

CONCLUSION

In summary, I believe the FY 1985 budget request supports a balanced, forward looking program. This balance is achieved by the continuation of the ongoing program, the initiation of two major new starts and involvement in the planning for the Space Station which holds much promise for the advancement of space science and applications.

As I noted in the beginning, the Space Science and Applications program has established a long tradition of achievement. We have made great strides in understanding the universe; learning about the Earth as a planet and developing useful applications of space science and technology. The FY 1985 budget represents a commitment to maintain the momentum in scientific and technical excellence that has had such an important impact on the nation and the world--to continue the outstanding effort of the past, to initiate new activities, and assure the preservation of the scientific research base that is critical to U.S. leadership in space.

Fig. 1

IRAS VIEWS THE CENTER
OF OUR GALAXY
FAR INFRARED
VISIBLE LIGHT PHOTOGRAPH

Fig. 2

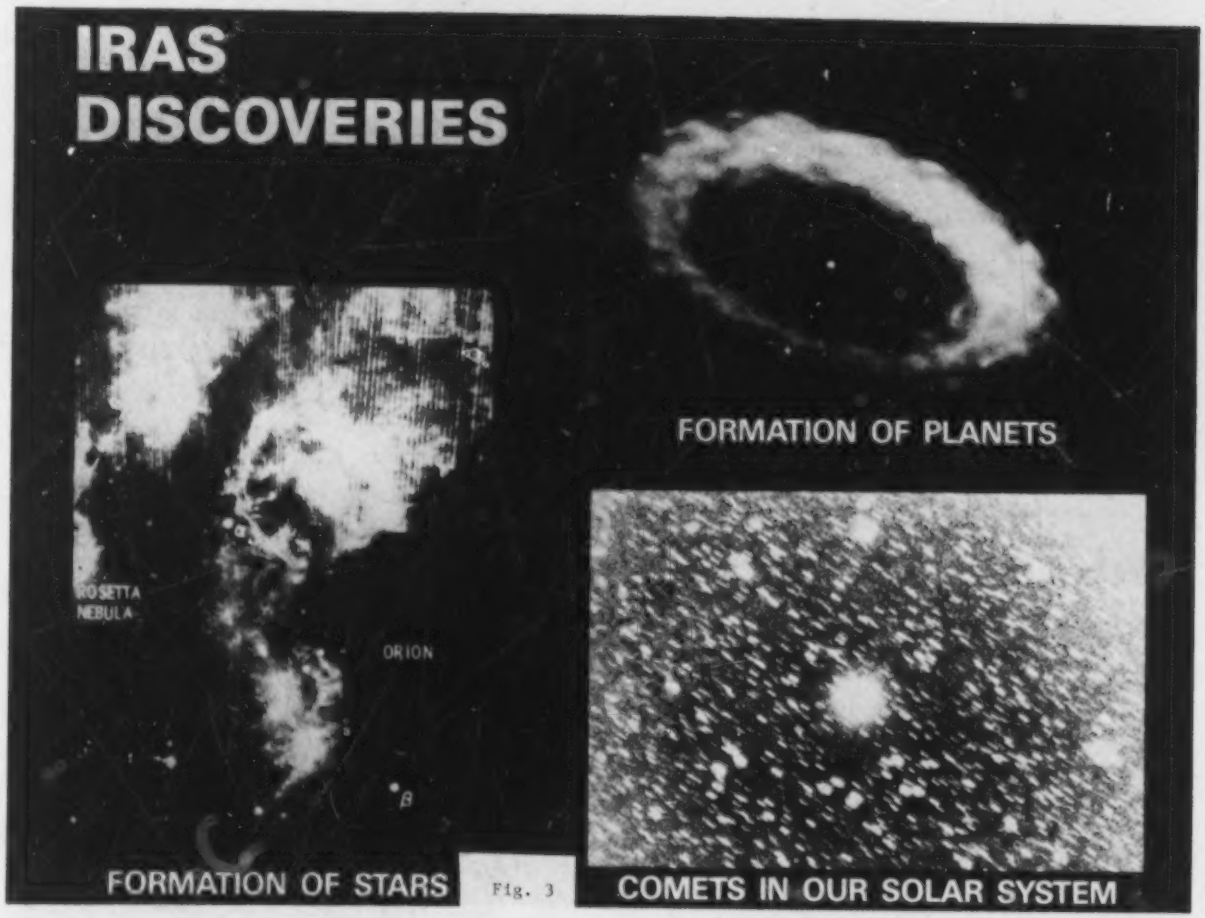

IRAS
DISCOVERIES
FORMATION OF PLANETS
ROSETTA
NEBULA
ORION
β
FORMATION OF STARS
COMETS IN OUR SOLAR SYSTEM

Fig. 3

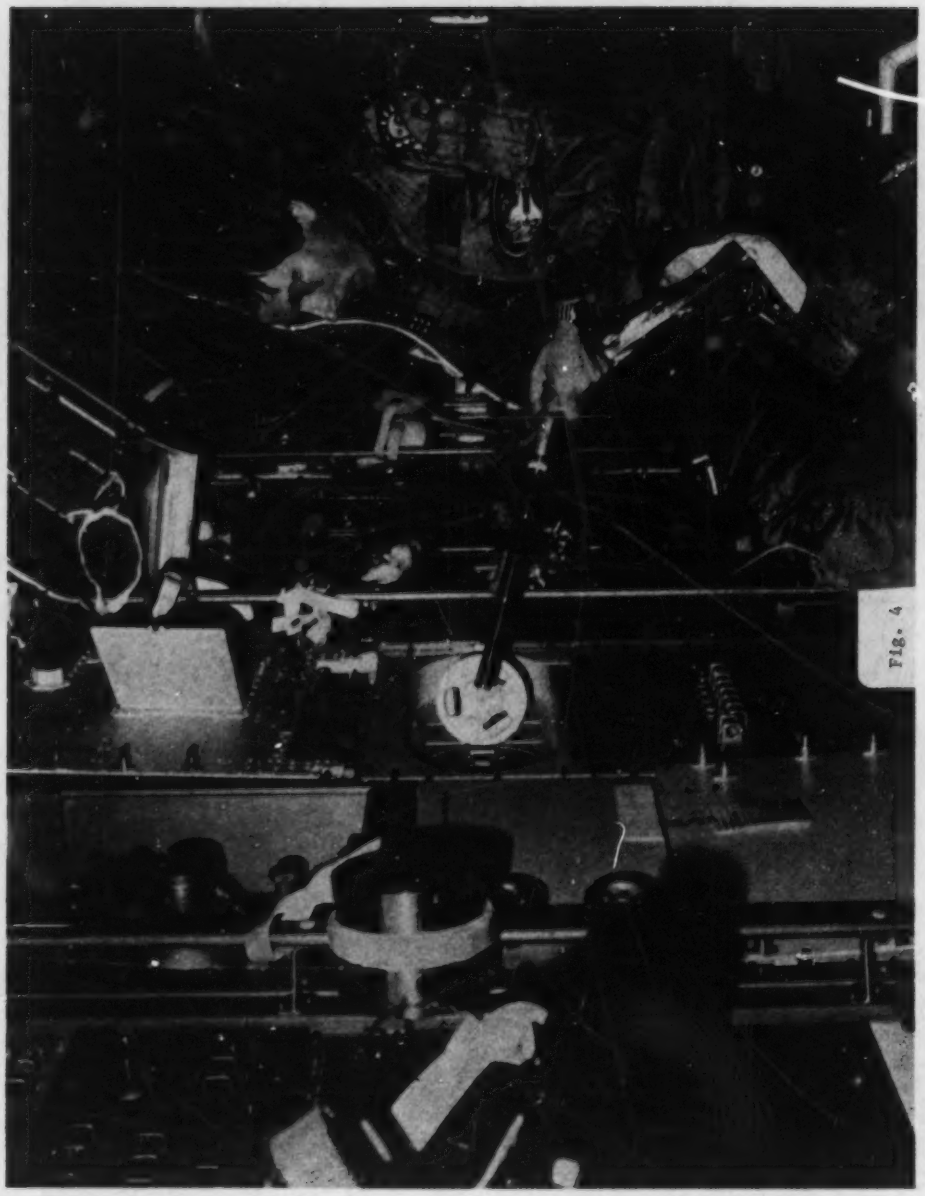


Fig. 4

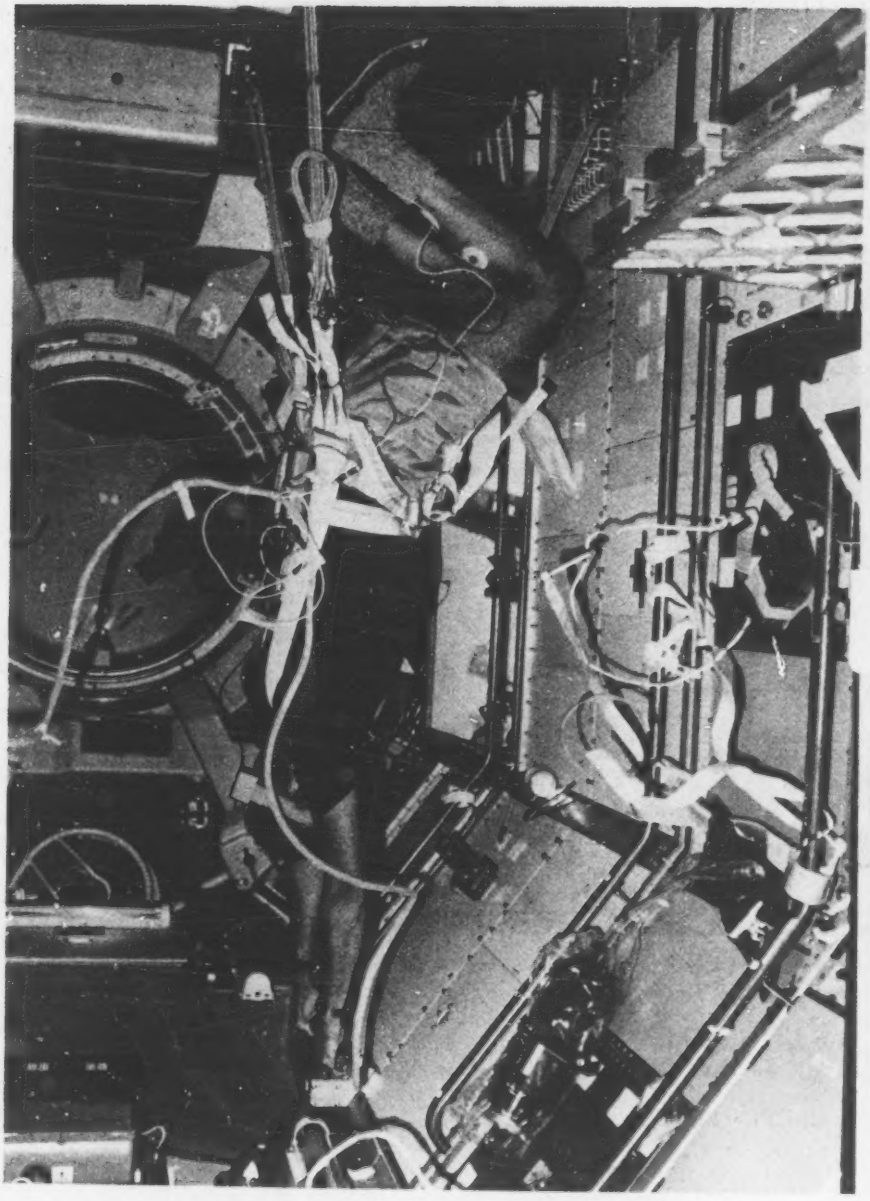


Fig. 5

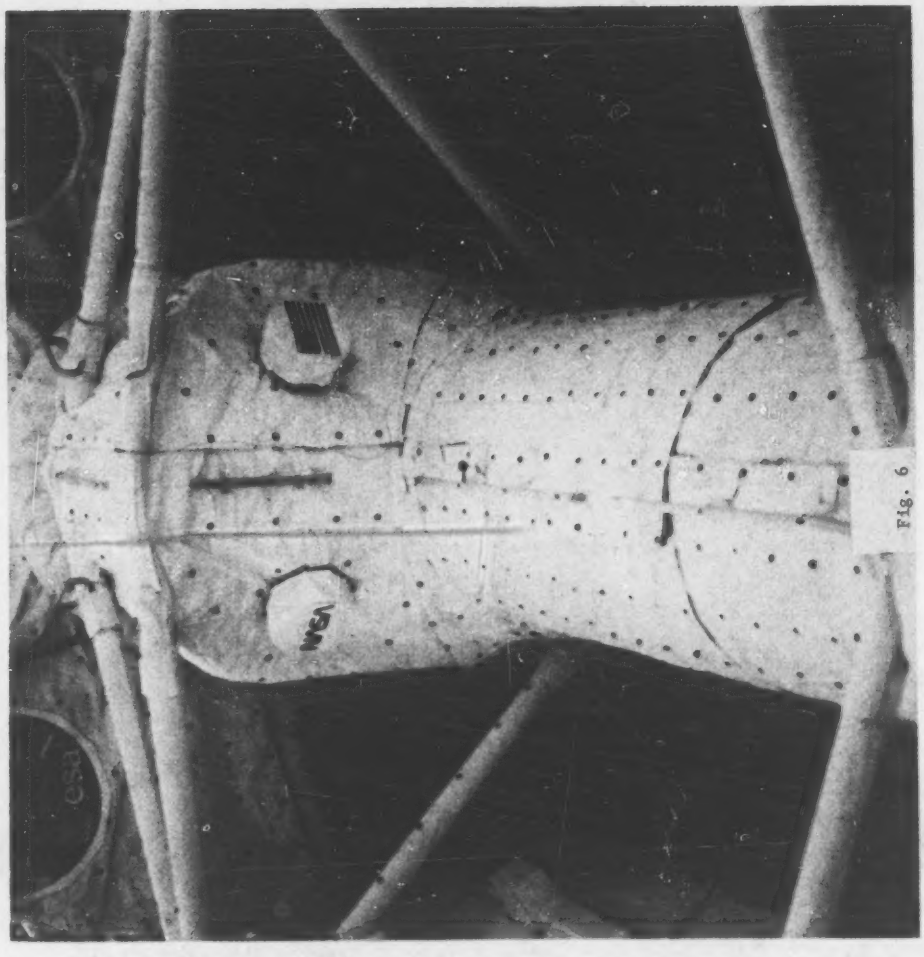


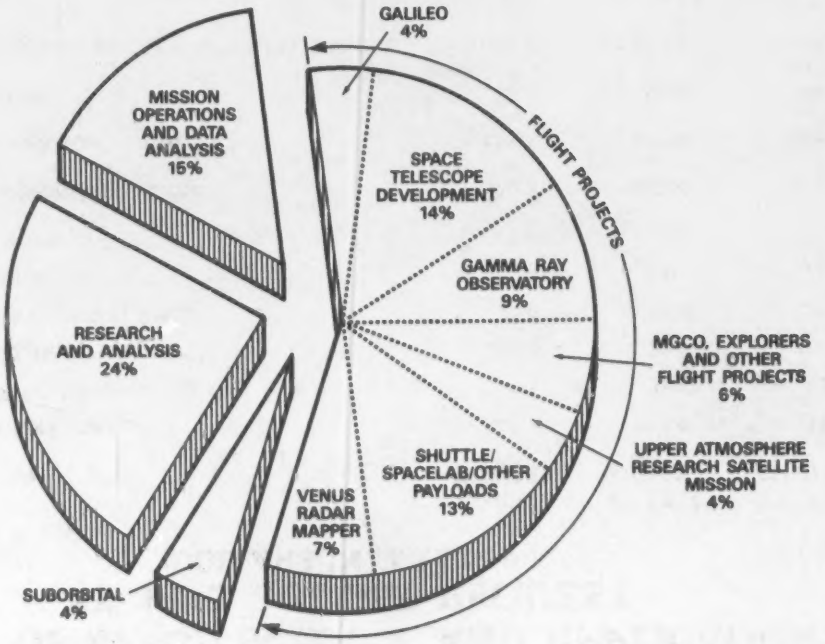
Fig. 6

OFFICE OF SPACE SCIENCE AND APPLICATIONS
FY 1985 BUDGET REQUEST
(DOLLARS IN MILLIONS)

	FY 1983 BUDGET	FY 1984 BUDGET	FY 1985 REQUEST
SPACE APPLICATIONS TOTAL	347.7	291.0	344.1
SOLID EARTH OBSERVATIONS	128.9	75.4	63.6
ENVIRONMENTAL OBSERVATIONS	156.9	162.0	220.7
MATERIALS PROCESSING IN SPACE	22.0	23.6	23.0
COMMUNICATIONS	32.4	21.1	20.6
INFORMATION SYSTEMS	7.5	8.9	16.2
PHYSICS AND ASTRONOMY - TOTAL	470.3	567.6	677.2
PLANETARY EXPLORATION - TOTAL	186.4	217.4	286.9
LIFE SCIENCES - TOTAL	55.7	58.0	63.3
TOTAL OFFICE OF SPACE SCIENCE AND APPLICATIONS	1060.1	1134.0	1371.5

Fig. 7

OFFICE OF SPACE SCIENCE AND APPLICATIONS
RESEARCH AND DEVELOPMENT BUDGET—FY 1985
(DOLLARS IN MILLIONS)



$1,371.5

Fig. 8

QUESTION E-1:

Please furnish complete runout costs for the following programs now in development.

ANSWER E-1:

	Prior Years	FY 1984	FY 1985	BTC Range	Total
Hubble Space Telescope	652.7	195.6	195.0	131.7	1175.0
Venus Radar Mapper	-	29.0	92.5	228-278	350-400
Gamma Ray Observatory	50.7	86.2	120.2	168-218	425-475
Galileo	486.2	79.5	56.1	208-288	830-910
Mars Geoscience/Climatology Orbiter	-	-	16.0	284-359	300-375
Upper Atmosphere Research Satellite	20.0	20.0	60.7	529-599	630-700
N-Ross Scatterometer	-	-	15.0	105-120	120-135
Advanced Communications Technology Program	20.0	5.0	5.0	70-100	100-130

QUESTION E-2:

a. Please provide an analysis of the technical differences and points of commonality between the Ka-band communications system proposed by Hughes Galaxy and NASA's Advanced Communications Technology Satellite (ACTS) program as originally proposed in FY 1984.

b. Please also compare the Hughes proposal and the FY 1985 ACTS proposal.

ANSWER E-2:

a. A comparison of the Hughes Ka-band filing and the ACTS flight program previously planned (RCA proposal) is attached.

b. The ACTS program has been restructured to exclude the flight test, but technology development required for future communications satellites will be continued through ground testing. The ground test program will allow many of the original ACTS program goals to be accomplished. Hardware will be developed for the critical technology elements which will further reduce the risks associated with placing any ACTS type flight system into orbit. More specifically the program will prove the capability of the multibeam antenna, the baseband processor and the Intermediate Frequency (IF) switch matrix to perform in a communication system. A complete end-to-end communication system test will be conducted to verify that the advanced system concept for achieving rain compensation, network control, system synchronization and user access is feasible. Finally the ground test program will

provide a first estimate of the communications quality, reliability, and availability.

QUESTION E-3:

What does the ground test and simulation portion of the new ACTS program entail and what will be learned from it?

ANSWER E-3:

ACTS has been restructured to be a ground test program. It will develop a communications system test bed which includes ground terminals, a master control station, and a communications package based upon refined Proof-of-Concept approaches. The communications package will include an antenna capable of handling a multiple scanning and fixed spot beams, low noise receivers, a baseband processor, an intermediate frequency (IF) switch matrix and a traveling wave tube amplifier. The test bed will simulate satellite motion, propagation effects and user messages. Extensive system testing will be performed to verify system performance including bit error rates and an ability to overcome propagation losses.

In developing this restructured program we considered potential achievements which are listed below: Advances the state of readiness of component technologies;

- Produces multibeam communications system hardware and software essential for system evaluation including ground terminal and master control station segments;

- Establishes the validity of component and system interfaces;

- Evaluates components in a representative communication system with the simulation of atmospheric and satellite motion effects.

We believe that the restructured ACTS ground test program coupled with the recently announced private sector activities planned for the late-1980's will be sufficient to maintain U.S. preeminence in satellite communications.

QUESTION E-4:

Aside from market and financial incentives, what additional knowledge would be gained by a flight test program for the ACTS system?

ANSWER E-4:

A flight test would provide a complete space-earth test and evaluation of the acquisition, synchronization and stability of the entire network communication and control system with rain fade compensation. The ability to compensate for satellite motion to account for message delays to about five nanoseconds is a major implementation uncertainty.

A demonstration of the readiness of the ACTS technology would result from a flight test program. A flight test would include an experimenter program involving system suppliers, ground terminal manufacturers and communications users who would contribute ground

terminal hardware and test data to evaluate commercial implementation risks and benefits.

QUESTION E-5:

What, if any, differences exist between the time division multiple access technology goals of the ACTS program and that planned for the INTELSAT VI system?

ANSWER E-5:

Both the INTELSAT VI and ACTS systems will adequately develop the network control software and hardware technology for Satellite Switched Time Division Multiple Access (SS/TDMA) systems based upon matrix switched fixed beam approaches. However, INTELSAT VI will not develop or use the more advanced, higher risk SS/TDMA approach which depends upon the base band processor scanning beam technology needed for service many of the traffic needs in the 1990's. The base band processor scanning beam technology is the major thrust of the ACTS Program.

QUESTION E-6:

What could be learned from an ACTS flight program based on a shuttle flight test? What would be the cost differences between such a shuttle based flight program and the originally planned geosynchronous satellite flight program?

ANSWER E-6:

A shuttle flight test of an ACTS communication payload (transponder and multibeam antenna) was considered during early program planning and was dropped because of the limited technology payoff and mission compromises. An example of the difficulty encountered with such a flight test is the limited visibility time due to the spot beams and relative motion between the shuttle and a ground location. For a typical shuttle mission of seven days, approximately ten experiment periods would occur, each lasting for 69 seconds, with the ground stations located in an optimum location in central Florida. This configuration would not provide useful experiment data.

Estimated cost comparison of original ACTS Program vs. a Shuttle Based Communications Program excluding shuttle launch cost is shown below:

ACTS Geostationary Flight Test	$325-425M
ACTS Shuttle Experiment	$200-300M

A shuttle test flight could potentially provide some useful data about the ACTS antenna pattern performance if the shuttle flight were used in conjunction with the space station as a second part of the test link. No cost information is currently available concerning this test.

QUESTION E-7:

NASA has its own communications needs and with more Shuttle flights (perhaps many of extended duration), Space Telescope and other

scientific facilities, and of course, eventually the Space Station, NASA may need more capacity than TDRSS can provide:

a. What is NASA doing to support its own future needs?

b. How might ACTS be restructured to contribute to meeting future NASA needs?

ANSWER E-7:

a. NASA is currently studying the requirements for and carrying out system studies for an advanced tracking and data relay system as a second generation TDRSS. The ACTS program will produce technology alternatives which may be useful for future TDRSS designs.

b. The experimental program being planned for ACTS will be fully exploited to support NASA's needs as well as U.S. industry needs.

QUESTION E-8:

Last year, (FY 1984), the Congress augmented the Planetary/Research and Analysis budget. This year, you have reduced the number below the 1984 budget. Why? What activities will be cut?

ANSWER E-8:

The requested level in this area reflects the difficult balance that NASA has sought to achieve in the planetary exploration program between mission activity and supporting research. Both are equally essential to the overall program. The intent of the Solar System Exploration Committee was to provide more flight opportunities to the Planetary Exploration community. NASA has responded by requesting the initiation of the Mars Geoscience/Climatology Orbiter in FY 1985; thus, the total Planetary Exploration request reflects a significant increase from FY 1984 to FY 1985.

QUESTION E-9:

The Solar System Exploration Committee (SSEC) has recommended a minimum core program for Planetary Exploration. The two most highly recommended missions are in the budget (VRM, MGCO). However, the primary thesis of the SSEC was that a minimum, core program be estimated and maintained. Part of this was maintenance of a continuing budget. Another important part was establishing a "Planetary Observer" budget which like the Explorer budget in Physics and Astronomy, would be an ongoing level-of-effort budget to fund inexpensive missions. The first Planetary Observer mission recommended by the SSEC, the Mars Geoscience/Climatology Orbiter, is in the budget, but the Planetary Observer program is not. The main point of the SSEC program was the need for stability that would be provided by such a program.

a. Do you agree with the SSEC recommendation for a core program?

b. What cost savings could you project by establishing a continuing program of planetary observers, as recommended by SSEC, in which the space segment hardware is standardized and procured on a long-term basis?

c. How can we and the Planetary Science community be convinced that you intend to support this discipline?

d. What are your plans for following the rest of the SSEC recommendations?

ANSWER E-9:

a. The core program formulated by the SSEC is intended to establish a long-term, stable base for the planetary sciences in which scientifically exciting missions can be carried out within a realistic, sustainable budget. I agree with the basic elements of the core program.

b. For a continuing program of Planetary Observers, in which the sequential procurement of basic spacecraft buses and multi-missions instruments was planned, the missions optimally scheduled and operated from a multi-mission facility, and the program managed as a single entity, approximately 15-20% could be saved over the cost of each mission being separately implemented.

c. I have stated my commitment to restoring solar system exploration to an eminent position in NASA's space science program and our actions over the past two years have demonstrated that commitment. A concerted effort has been made to restore stability and continuity to the program, and I believe we have succeeded with the initiation of the Venus Radar Mapper Mission last year and the inclusion of the Mars Geoscience/Climatology Orbiter (MGCO) in the FY 1985 budget request. In addition, we are actively planning for the Voyager encounter with Neptune and we are supporting completion of the development and launch of Galileo and ISPM. Providing a healthy financial base for planetary science is a very high priority in my mind and I believe this can be evidenced by the mission outlined above.

d. Our plans are to implement the SSEC mission set in the sequence recommended by the SSEC. As you know, following MGCO in the SSEC's priority is the Comet Rendezvous/Asteroid Flyby Mission, the Saturn Orbiter/Titan Probe, the Lunar Geochemical Orbiter, etc. The next new initiative for which we will be requesting approval will be the Comet Rendezvous/Asteroid Flyby Mission.

QUESTION E-10:

In October 1983, the NASA Advisory Council released its recommendations from its study on the "mission of NASA."

a. What is the current status of the study?

b. Have you formulated a formal response to the Advisory Council's recommendations?

c. The Council has recommended a stepped-up program in the space sciences, involving exploration of the solar system and enhanced activity in the earth sciences. These recommendations go beyond the core program recommended by the Solar System Exploration Committee (SSEC). Can you describe NASA's plans, including budget, in this area?

ANSWER E-10:

a. The study was completed and submitted to NASA in October 1983.

b. A formal response to the Council's recommendations is being prepared.

c. NASA's planning, both in solar system exploration beyond the SSEC's core program and in studies of the Earth, is not yet sufficiently far along to describe in terms of specific missions, schedules, and budgets. In fact, additional studies by the SSEC and a study of Earth science programs by a new group, the Earth Systems Science Committee (both under NASA Advisory Council auspices) are expected to provide recommendations that will be used in guiding planning in both areas. When the results of those studies are available, NASA will be able to evaluate the respective recommendations and incorporate them appropriately in its planning.

QUESTION E-11:

The materials processing program is down in the FY 1985 budget. At the same time, the program is being advertised as an important activity for space station.

a. What activities are being cut from the Materials Processing program as a result of the budget cut?

b. What funding will be made available in FY 1985 for the university center (or centers) we recommended last year? What was the 1984 funding level?

c. You state (page 17) that the MPS Program has recently been assigned the "Physics and Chemistry Experiments" (PACE) from the Office of Aeronautics and Space Technology. Coupled with the decreasing funding, don't these increased responsibilities amount to a further dilution of the program?

d. How much MPS funding is carried in the various "Spacelab/Shuttle PAYLOAD" lines in other parts of the budget? Please identify.

ANSWER E-11:

a. No activities will be deleted in the fiscal year 1985 budget. During the past year, OSSA has taken steps to reorganize and strengthen the management and role of the microgravity disciplines to take full advantage of the operational Space Shuttle. In addition to reassessing the research and analysis portion of the program, emphasis is being placed on the construction of small, relatively low-cost instruments for flight. The FY 85 budget will allow us to do this in an orderly way.

b. Although the exact number of centers and their respective funding levels has not been established at this time, we expect to be able to select between one and three universities in FY 1984. Assuming a grant level of between $300K and $400K for each Center, we will award between $300K and $1200K in this Fiscal Year. These awards are typically committed for three years at the same level of funding;

therefore, we would expect to spend between $300K and $1200K in FY 1985.

c. The Physics and Chemistry Experiments (PACE) that were transferred from OAST to OSSA form a natural part of the Microgravity Science and Applications Program rather than being a dilution of the ongoing program; the PACE Experiments actually strengthen the investigations of materials. These experiments in fundamental physics and chemistry will form the backbone of a Flight Research Program which will allow a thorough understanding into the production of materials. Without this fundamental understanding, processes can only be performed empirically. With this understanding, new information regarding the microstructure of elemental substances will become known and can be applied in a practical way for the benefit of mankind. A specific example can be found in the PACE combustion program which was explicitly cited by the STAMPS Committee of the NRC in 1978.

d. There is approximately $2 million carried in the Spacelab/-Shuttle Payload line in FY 1985 for completion of the integration and the data analysis for the Fluid Experiment System/Vapor Crystal Growth (FES/VCG) Experiment that is due to fly on the Shuttle in December 1984. That is the only area outside of the Materials Processing line where any MPS funding is carried.

QUESTION E-12:

In the Materials Processing area, ground-based investigations, analysis and studies are being reduced from $13.1 million in FY 83 and $14.0 million in FY 84 TO $11.7 MILLION IN FY 85. The $3.0 million difference in FY 84 is the result of a realignment of program funding between ground based and flight research.

a. Doesn't this run counter to the long standing policy recommendations (see NRC Report, "Materials Processing in Space," 1978) to provide a sound base in terrestrial science as opposed to flight testing?

b. Why is the policy being shifted at this point?

c. What specific programs are being dropped or diluted by this proposed shift?

ANSWER E-12:

a. The STAMPS Committee Report specifically states "The experimental parts of this program should be chosen with great care from earth-based scientific and technological work that clearly indicates that recourse to the space environment might advance the results." NASA, since the issuance of the STAMPS Report in 1978, has followed that guidance and has seen the early research and analysis work arrive at the point where "recourse to the space environment" will clearly advance materials processing. It is the intent of NASA to pursue a strong ground-based research and analysis program which will naturally lead to a continuation of the investigations in the space environment.

b. There is no policy shift; rather, there is a new and exciting opportunity available in materials processing because of the advent of

an operational Space Shuttle. Between the issuance of the STAMPS Report and today, only ground-based facilities such as droptubes, droptowers, aircraft and sounding rockets were available for experimentation. All of these, of course, allow only relatively short periods of gravity-free time. With the Space Shuttle flying on a regular basis, days of microgravity, rather than seconds, are now available for our experimenters.

c. No programs are being either dropped or diluted by this shift. The flight experimentation portion of a research effort in microgravity science is a natural and planned outgrowth of the fundamental ground-based work that is required.

QUESTION E-13:

You have recently commissioned a study on Universities and NASA Space Sciences which has resulted in recommendations for increased investment in University equipment, graduate student fellowships, and more data analysis.

a. What do you plan to do in response to these recommendations? Please provide a response specific to each recommendation.

b. Is there an identifiable response to these recommendations in the budget?

c. Is there any reason why you cannot establish a university capital equipment line item?

ANSWER E-13:

a. The NASA University Relations Study Group recommended $10M annually for equipment grants, $20M for data analysis and the establishment of a NASA graduate student study program as well as continuing studies on the relations between the NASA Centers and the universities and how to do science on the Space Shuttle in a more cost effective manner. The 1985 budget request has a substantial increase for funding to educational institutions. The amount available for procurement of university laboratory equipment is increased in Fiscal 1985 over the current year. Funding for data analysis has also increased. We have a graduate fellowship program between the universities and the NASA centers and are studying ways to extend this program in accordance with the recommendations of the NASA University Relations Study Group.

b. NASA's support of universities is an integral and important element of continuing research and development missions. The specifics of that support are contained within the various programs and research disciplines. Specific responses are, therefore, not identifiable in the budget as constructed.

c. The NASA budget is structured to conform broadly to the missions and disciplines around which the agency is organized, e.g. Physics and Astronomy, Planetary Exploration, etc. We do not believe that a university capital equipment line is a necessary addition in order to achieve the objectives of the study.

QUESTION E-14:

Please provide the following information on the dollar amount of procurement awards made directly to universities for the years FY 1980 and FY 1984.

a. Total awards agency-wide.

b. Amount identifiable under the "Research and Analysis" line items in each major program area (i.e., Planetary Exploration, Physics and Astronomy, etc.) in the Space Science and Applications area.

c. Amount allowed for capital equipment purchases.

d. Please account separately for the amounts that were merely passed through universities to contractors, e.g., to build instruments.

e. Concerning the "pie chart" you presented at the hearing which showed that flight programs are less than half of the OSSA budget: Could you recalculate a breakdown by pulling out of MO&DA the funding for operation of flight projects and out of R&A the funding for advanced development of flight projects?

ANSWER E-14:

	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984 Est.
a. NASA-wide awards	$177.3M	$191.1M	$185.6M	$209.8M	$225M-$235M
	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984
b. Life Sciences	10.7	12.0	14.5	17.0	
Communications	1.4	0.9	0.6	0.6	
Planetary Exploration	32.4	33.7	33.1	33.3	
Physics and Astronomy	40.2	46.9	48.7	58.7	
Materials Processing	2.8	2.7	3.4	4.1	
Information Systems	-	-	0.1	0.1	
Environ. Observ.	27.7	29.1	18.3	20.2	
Admin. & Res. Mgmt.	0.4	0.1	0.4	0.1	
Tech. Transfer	1.0	0.6	-	-	
Tech. Utilization	4.3	3.0	-	-	
TOTAL	121.0	129.0	119.1	134.1	150-160

The FY 1984 total is an estimate and the breakdown between program areas is not available since proposals are evaluated and contract awards made continuously throughout FY 1984.

c. NASA does not compile a listing of capital equipment purchased by the academic community in the performance of NASA-awarded contracts. The best "ballpark" estimate FY 1980 through FY 1984 is that about 10% of the total awards was used for equipment purchases.

d. This is very difficult to determine since the NASA accounting system concentrates on the prime contractor, in this case a university, and does not require any reporting beyond this level.

e. The "pie chart" for OSSA's FY 1985 Budget has been modified to show the operation of flight projects within MO&DA and the advanced development of flight projects within R&A.

QUESTION E-15:

Over the past several years, this Committee has continued to be concerned over the space telescope cost overruns, schedule delays, and its impact on other science missions. The FY 85 budget request of $195 million is considerably greater than the $69 million projected last year.

a. What is your current estimate of any schedule and technical problem areas that may lead to additional cost overruns?

b. What do you consider to be the most critical milestones and technical problems remaining?

c. How would you characterize the risk associated with the system integration phase? What time have you allotted to system integration? What would be the impact of allowing more time for system integration?

d. Do you feel that you have sufficient funds and reserves remaining to avoid future supplemental budget requests or reprogramming actions?

ANSWER E-15:

a. The Space Telescope schedule remains very tight with the Support System Module and the Optical Telescope Assembly slightly behind schedule. These delays were caused by temporary problems that have been addressed, and a recovery plan is being implemented. The current critical schedule elements are the Data Management System, Electrical Power System, and Electrical Ground Support Equipment development, as well as the Fine Guidance Sensor/Optical Control Subsystem integration and scientific instrument testing. All known technical and schedule problems are being addressed, but the possibility of future problems or anomalies occurring during testing, does place risk on our current schedule. However, it is our current estimate that the program will be completed within our revised cost estimate of $1,175 million.

b. A program as large and complex as Space Telescope has many critical milestones and potential technical problems. The current technical challenges being faced by the program are primarily related to integration and test as opposed to development. The overall system and subsystem on-orbit performance is a long term technical concern. Key milestones for the program include Support System Module Equipment Section functional testing delivery of the scientific instruments after rework to Lockheed, delivery of the Optical Telescope Assembly to Lockheed, completion of the Science Operations Ground System, and completion of assembly and verification of the total Space Telescope system.

c. The Assembly and Verification (A&V) phase for the Space Telescope is currently scheduled to begin during the first quarter of FY 1985, and continue for approximately fifteen months. This is a critical phase of the program, requiring all components to be mated and tested, and will result in a totally integrated, flight-ready system. It is a high risk period, and will require careful and continuing management attention. Lengthening the A&V schedule would allow for additional testing and provide schedule contingency thus reducing risk, but would result in increased cost. In our judgement

prudent planning of the A&V schedule has occurred and sufficient time has been allocated to ensure successful completion in a timely and efficient manner.

d. Although the Space Telescope program continues to provide many challenges, it is our current assessment that we can complete the development activities within the estimate of $1,175 million.

QUESTION E-16:

Early results from the Spacelab I mission suggest that observations in the ultraviolet have been compromised by an apparent background in the ultraviolet.

a. With so many Shuttle Science missions such as the Space Telescope, and the Astro I mission, critically dependent on the absence of such a background, what are you doing to study this phenomenon?

b. As early as STS-3, NASA has been aware of a glow phenomenon, which may account for such a background. What is being done to characterize it and its spectral characteristics?

c. Assuming that this glow scales with the concentration of atomic oxygen, can the space telescope be placed in an orbit sufficiently high to reduce the U.V. background below the established Level I specifications? How would periods of high solar activity affect this?

ANSWER E-16:

a. The results from Spacelab 1 are under review and the implications of those results to other missions are being assessed. Two ultraviolet spectrometers ideally suited for studying the background phenomenon, will be flown on STS-19 and should shed much light on the Spacelab 1 results. It is believed that the source of the apparent background is either (1) glow from equatorial emission bands, (2) atmospheric glow observed during astronomical twilight or (3) localized Shuttle induced glow from interaction with the residual atmosphere. Sources (1) and (2) do not represent threats to future missions in that they are readily avoidable and source (3) can be minimized by going to higher altitudes and constraining the Shuttle orientation.

b. Flight experimentation involving a 35mm camera outfitted with an image intensifier and an objective grating has been conducted on STS-4, STS-5, and STS-8. This activity has yielded much knowledge of the glow (e.g., altitude and orientation dependence, material surface affects and spectral characteristics in the visible wavelength region). Further refinements of this experimentation are planned for STS-14. The ultraviolet spectrometers planned for flight on STS-19 should add to our understanding of the glow problem.

c. Current plans are to place the Hubble Space Telescope (HST) into a 320 nautical mile orbit through a direct insertion by the Space Shuttle. This will be accomplished by using the lightest of the Space Transportation System orbiters thereby maximizing the insertion altitude. Since atomic oxygen number density decreases exponentially with increasing altitude, the HST altitude (320 nautical miles) will

experience less "Shuttle Glow" than at the altitudes at which observation have been made to date (from 120 to 165 nautical miles). The predicted atomic oxygen number density at the HST altitude would range from 50 to 500 times less than that at typical Shuttle orbital altitudes (depending on the phase of solar activity). Although the glow effects in the ultraviolet are not yet quantified with respect to the Space Telescope we are exploring other options of achieving still higher altitudes due to the extreme sensitivity of the telescope. The higher altitudes would not only reduce the glow effects but would also improve the Pointing and Control System performance and orbital lifetime; both are presently limited by atmospheric drag.

Periods of high solar activity will have a two-fold effect on the Space Telescope. High solar activity increases atomic oxygen number density. It also increases atmospheric drag and the orbital decay rate of the satellite. When the altitude decays to approximately 295 nautical miles, the Space Telescope must be reboosted to the higher altitude, primarily due to performance degradation. Thus a higher altitude not only reduces the glow phenomenon and materials degradation, but also delays the initial reboost. There are also operational methods to reduce or eliminate the effects of the glow problem such as avoiding the pointing of the HST close to the actual orbital ram flow sector. The Space Telescope Program is actively pursuing all of these options.

QUESTION E- 17:

The Space Telescope as well as many other science missions are critically dependent on the timely launch and reliable performance of the TDRSS.

a. How will delays in solving the I.U.S. (Inertial Upper Stage) problem impact the Space Telescope?

ANSWER E-17:

a. The Hubble Space Telescope (HST) requires the availability of two Tracking and Data Relay Satellites (TDRSS) in order to optimize the science return from the telescope. However, the HST can function and produce scientific results with only one operational TDRSS. The impact of having only one operational TDRSS is to reduce the rate at which science will be returned. It is our plan to launch the HST on schedule in 1986 as long as at least one TDRSS is operational at that time.

QUESTION E-18:

The results of the IRAS mission have been notable. But they are a preliminary survey needing follow up.

a. What plans does NASA have for continuing astronomical missions in the infrared (such as the Shuttle infrared Telescope Facility (SIRTF)?

b. Will SIRTF be built as a Shuttle payload, to be used on a platform in conjunction with Space Station, or as a free flyer? Are all these approaches mutually exclusive? (That is, could a Shuttle payload eventually go onto a platform associated with Station?) Why?

ANSWER E-18:

a. NASA's plans assume the continuation of astronomical missions in the infrared and submillimeter region of the spectrum with a meter class, cryogenically cooled telescope (SIRTF) which would be followed by a large aperature (approximately 15m dia.) deployable telescope.

b. The IRAS mission established the need for long-duration observations with a telescope. IRAS also demonstrated the management of superfluid helium in zero g and long-lived dewar technology. Infrared detector technology is also maturing and approaching photon counting capability and limitations, so that instrument detector changes may not be needed as frequently as originally thought. Therefore, we are examining three options on implementing SIRTF. These include (1) developing the facility as a Shuttle payload, (2) proceeding directly to a long-lived mission which may be a free flyer or (3) part of a platform associated with the Space Station. When adequate study of the options with the scientific community has been completed, we will make a decision as to the appropriate implementation mode. The implementation approaches to these options may be exclusive depending on the constraints and conditions applied.

QUESTION E-19:

In the 1982 Unispace Conference in Vienna, NASA announced plans for a Global Habitability program.

a. In the interim, what progress has been made in formulating specific scientific objectives and plans to carry out this commitment?

b. Why is the budget description for Global Habitability fragmented among a diverse array of other programs rather than as an identifiable budget item?

c. What has been the reaction of the State Department, NOAA, and other agencies to the Global Habitability Program? Can you supply for the record any letters or documents relevant to your answer?

d. What has been the reaction of other countries and international bodies such as UNEP to the Global Habitability Program? Again, can you supply any documentation for the record?

e. What entity do you envision should be the international focal point for the Global Habitability Program?

f. The Global Habitability Program involves a great deal of biologically oriented research. Is NASA the appropriate agency to undertake this work? What interagency participation do you think would be beneficial in this area?

ANSWER E-19:

a. Since the Unispace conference in 1982, four working groups drawn from the the earth sciences community have addressed the scientific issues and objectives of Global Habitability. All the working groups have completed their studies, and three of the groups have published the following documents:

- "Global Change: A Biogeochemical Perspective"

- "Land-Related Global Habitability Science Issues"

- "Global Biology Research Program"

The fourth working group will publish its results, "Global Change: Physical Processes in Global Biogeochemical Cycles," later this year.

In April of 1983, NASA's solid earth research activities were combined with oceans and atmospheric research to form the Earth Science and Applications Division within Space Science and Applications. The joining of these research elements will facilitate the interdisciplinary earth science research necessary to carry out global habitability types of activities. A subcommittee of the NASA Advisory Council has been established to advise NASA, and to develop implementation strategies for a potential Global Habitability program. The makeup of this subcommittee has been chosen to assure representation of the science disciplines as well as other government agencies in related areas of interest.

b. Activities relevant to a Global Habitability program are underway within the framework of present ongoing programs. Since we have not yet completed program planning for global habitability, we have shown the relevant ongoing research and the related research budget items the same as in previous years. We have requested modest new funds to begin to look at interdisciplinary science issues related to global habitability. While we have made significant progress in developing the scientific basis for global habitability, review of the science base is still underway by the National Academy of Sciences. When this review is completed, we will be better able to identify those budget items which clearly support the science objectives of global habitability.

c. Our recent interactions with the State Department have primarily been in coordinating Global Habitability related NASA cooperation with the United Nations Environment Programme and with the U.S. Man and Biosphere Program. The State Department has been supportive and constructive in assisting NASA in establishing these cooperative activities.

NOAA has been generally supportive of a Global Habitability program and has expressed a willingness to cooperate on related activities. We have also met with Mr. Ruckleshaus at EPA and Assistant Secretary Bentley (USDA), and have received their strong support of the program. Most agencies are providing representation on the Earth System Sciences Committee.

d. Discussions with international organizations and representatives of foreign governments have been limited to discussions of the general Global Habitability concept. Active interest in the concept has been expressed by representatives of the United Kingdom's Natural Environment Research Council and Science and Engineering Research Council, the European Space Agency, the Federal German Government, Saudi Arabian National Center for Science and Technology, World Meteorological Organization, United Nations Environment Programme, Food and Agriculture Organization, and United Nations University. Discussions with foreign agencies will continue at the conceptual

level until formulation of the Global Habitability Program is complete.

e. NASA has approached the National Academy of Science (NAS) to coordinate U.S. scientific efforts associated with Global Habitability, and to represent the U.S. science communities in the international arena through the International Council of Scientific Unions. Meetings were held with NAS to discuss the government-wide formulation of the effort. NAS has proposed a concept for a broadly-based International Geosphere Biosphere Program (IGBP), of which Global Habitability will be a part. It is anticipated that IGBP planning and implementation would evolve over approximately a five-year period. We support the concept and objectives of the IGBP, and feel that such a program may ultimately provide needed scientific coordination for Global Habitability and other international scientific programs. We have also asked NAS to consider the scientific and societal merit of Global Habitability as an entity separate from the IGBP, as well as to consider the program in the context of a more broadly based IGBP. In either case, it is envisioned that ICSU would be the international focal point.

f. An important element of Global Habitability will be the study of long-term changes in certain global biogeochemical cycles. These studies will require global data relating to coupled physical, chemical, and biological processes of the Earth's land, oceans, and atmosphere. Much of these data can be provided by NASA's space-based instruments. It is clear, however, that NASA alone cannot characterize long-term changes in these global biogeochemical cycles. Global Habitability must, therefore, be a program which involves cooperation with domestic agencies such as NOAA, EPA, and USDA, as well as other nations and international organizations, such as WMO, UNEP, and FAO.

QUESTION E-20:

Recently, the National Academy of Sciences issued a report outlining a proposal for an International Geophysical Biophysical (Geosphere Biosphere) Program (IGBP).

a. How does Global Habitability relate to this effort?

b. Do you think IGBP should necessitate any schedule adjustments in Global Habitability to acccommodate the coordinated measurements envisioned?

c. To what extent do you feel that the goals of IGBP to promote interdisciplinary and international coordination can be addressed by a global resource information system?

ANSWER E-20:

a. The Global Habitability Program will be a research program involving studies of the atmosphere, land, oceans, and biosphere to investigate long-term coupled physical, chemical, and biological changes in the earth's environment on a global scale. The program will be comprised of disciplinary and interdisciplinary research involving space-based, suborbital, land-based, and sea-based measurements, as well as laboratory, theoretical, and instrument

development studies. This is central to the goals and objectives of the proposed IGBP. The IGBP is somewhat broader in scope involving solar terrestrial and geodynamics research for which NASA has active research programs, and these will also be actively involved in the proposed IGBP. The composition of the newly formed National Academy of Sciences IGBP committee reflects the central role of studying the Earth's atmosphere, oceans, land, and biosphere, i.e. Global Habitability.

b. Much of the detailed planning for both programs remains to be done. This is especially true for IGBP. Coordination of the two programs is recognized to be vital as National and International participation is of utmost importance in the accomplishment of both programs. The initiation of the Global Habitability program may well precede that of the proposed IGBP by several years but given that both programs are expected to last more than a decade, and that they are both the synthesis of disciplinary and interdisciplinary research, (much of which is already ongoing), the two programs do not need to be initiated at the same time. In fact, not all elements of either program are at the same stage of maturity and as such these elements should be initiated at different times and proceed at different rates without detriment to achieving the stated goals of either program.

c. For programs such as Global Habitability and IGBP which will involve large volumes of data and information, a global resource information system is crucial if the goals and objectives are to be achieved. Efficient collection, archiving, and dissemination of diverse sets of data from diverse sources is recognized to be difficult, yet vital.

QUESTION E-21:

Over the past several years, Congress has encouraged NASA to plan for a global resource information system in order to promote better access to data and to increase the level of coordination in the earth sciences.

a. What is the current status of NASA planning in this regard?

b. When can we expect to see implementation?

c. How can we ensure that operational and monitoring data such as collected by NOAA could be appropriately integrated into such a data system?

d. Who should be primarily responsible for the system?

ANSWER E-21:

a. In October 1982, NASA's Information Systems Office prepared an internal draft Global Resource Information System Program Plan for review and coordination within NASA. In February 1983, an Executive Summary of the plan was prepared and forwarded to the House Subcommittee on Space Science and Applications. At this time, a low level effort is underway to continue concept development, and to coordinate developments in the science discipline oriented information system programs, which would provide a technological foundation for a

Global Resource Information System. Pilot programs are being conducted for the climate, oceans and land science communities.

b. Initial use of such a system by a subset of the science community could be expected approximately two years after new start approval and funding, with evolution and expansion of the system to serve the broad user community continuing through approximately ten years.

c. Integration of data sets collected and maintained by other agencies, such as NOAA, could best be integrated through a process involving:

1) interagency agreements to establish the intent and agreement to exchange data; and 2) technical and scientific working groups to define the scientific requirements and technical approaches to achieving data exchange. Such activity is being conducted now on a pilot basis between NASA and USGS.

d. Primary responsibility for the definition and implementation of the baseline technology and system implementation should reside with NASA, to draw maximum benefit from science discipline oriented information system programs currently in progress. The matter of full responsibility for system expansion and operation can be reviewed and resolved concurrent with the planning activities.

QUESTION E-22:

As you are aware, this Subcommittee has taken a major initiative in establishing policy and procedures for the transfer of land remote sensing systems to the private sector.

a. If this were to be successfully implemented, what would you envision the role of NASA to be in performing remote sensing research and development?

b. What plans do you have for systems such as Shuttle Radar, Stereosat, etc.?

c. Can you describe how remote sensing and "value added" type data manipulation could advance the goals of the Global Habitability Program?

d. Would NASA consider the provision of any type of launch services or technical assistance to a payload whose operation would not be fully compatible with the "open skies" principle?

e. Would you describe the arrangements NASA has made with the company SPARX? What do they plan to do with the data they collect? What restrictions, if any, have you placed on them with respect to data sales?

ANSWER E-22:

a. We do not envision that the transfer of land remote sensing systems to the private sector would result in any change to NASA's role in performing remote sensing research and development (R&D). NASA plans to continue to pioneer the development of new remote

sensing technology as well as techniques designed to extract new scientific information concerning earth science from these data.

NASA's continuing role in remote sensing R&D is critical for several reasons. First, it is important that the U.S. not relinquish its technological lead in remote sensing given the emergence of competitive foreign programs such as the French SPOT (programmed for launch in early 1985), the Japanese MOS-1 (planned for 1986), and the European Space Agency ERS-1 mission (1988). Secondly, maintaining the U.S. technological lead in remote sensing is directly related to the ability of U.S. remote sensing hardware, software and value-added enterprises to retain their preeminence in commercial markets. Should the U.S. fall behind in remote sensing technology, U.S. industry will likely suffer the consequences, particularly in overseas markets. Thirdly, advance remote sensing data from space is necessary to conduct earth science investigations directed toward understanding earth processes that may impact the long-term habitability of the Earth.

b. NASA plans to continue to advance the state-of-the-art in microwave remote sensing. Our specific plan for the Shuttle Imaging Radar (SIR) is to investigate the development of an upgrade from the current SIR-B configuration which will be flown for the first time in August 1984. The next configuration (SIR-C) will add another frequency and multiple polarization capability to the radar system. We are also looking forward to the first shuttle flight of the Multilinear Array in the 1987 time frame and subsequent development of a much improved Shuttle Imaging Experiment (SISEX). Ultimately, through incremental advances, NASA will have developed the science and technology necessary to design and implement the optimum Imaging Radar for use on the Space Station or other orbiting platforms. At present, we have no plans for Stereosat.

c. The successful advancement of the Global Habitability Program requires a multitude of remote sensing measurements and in situ measurements on a global scale, a data archival and retrieval system, and a strong capability to manipulate these data in earth science models relating to areas such as the various biogeochemical cycles. Remote sensing must measure both quantitative and qualitative variables that indicate taxonomic, geometric, physical, geological, chemical, and biological properties of earth phenomena. Once such data is obtained, multidisciplinary information systems, the ability to combine manipulate and enhance the data, and models are essential to ensure ease of data availability and analysis and to provide analytic support to a community of researchers. In some cases, inferences from remotely sensed data may have economic utility which could be exploited for profit. NASA's policy is to provide "open literature" on its data manipulation techniques which could be used by elements of the private sector.

d. NASA fully supports and is continuing to comply with the "open skies" policy. The provision of launch services, technical assistance or other government services to a land remote sensing payload will be in compliance with existing U.S. policy.

e. To date, the SPARX corporation has submitted the initial forms to purchase a Shuttle launch service in August 1984 and has requested that NASA enter into a Joint Endeavor Agreement (JEA) with them. They

have also submitted proposed JEA and data policy documents. Both launch service and JEA proposals are under review by NASA and, as yet, no firm arrangements have been concluded. The initial SPARX data approach would have them market the data collected through "area partners" who would purchase the data from SPARX. As proposed, the area partners would have full ownership of the data. Since no agreements have been concluded with NASA, restrictions have not been placed on SPARX to date. However, the provision of launch services, technical assistance or other governmental services to a private payload dictates compliance with existing U.S. policy.

QUESTION E-23:

You recently stated that NASA intends to "rescue" the failed Landsat-4 satellite.

a. When would this occur?

b. With respect to timing, how does this fit with the expected life of Landsat-5 (to be launched March 1, 1984)

c. How does this fit with the Administration decision to commercialize land remote sensing?

ANSWER E-23:

a. Retrieval of Landsat-4 cannot occur until a polar orbit Shuttle mission capability is available from the Western Space and Missile Center, Vandenberg AFB in 1986. Landsat-4 will be deboosted to a Shuttle retrievable orbit if the spacecraft exhibits additional solar panel degradation; otherwise Landsat 4 will continue to collect data.

b. The expected lifetime of Landsat-5 based on design is three years. The retrieval of Landsat 4 would be timed to occur while Landsat-5 is still operating.

c. There is no conflict with the Administration's decision to commercialize land remote sensing. When Landsat-4 is removed from service, its ownership reverts back to NASA. NASA is studying the advantages of a repair mission in-orbit versus retrieving and returning the spacecraft to Earth. Whether there are private sector interests in a Landsat-4 retrieval/repair mission for commercial opportunity is not presently known.

QUESTION E-24:

The NASA 5-Year Plan fundamentally lists a broad array of possible new starts. Why is it not possible to articulate an actual long range plan with a schedule for implementing the SSEC recommendations or any alternatives you feel are important?

ANSWER E-24:

The NASA 5-Year Plan projects desirable, long range activities, and the scientific rationale therefore, for space science. This plan is based on the integrated information from within and outside of the agency, including advice from the various NASA advisory committees, such as the Solar System Exploration Committee. Advice from all

sources is carefully considered, and the plan developed to project a balanced and forward looking program. The 5-Year Plan is updated annually to reflect new requirements, technical readiness, and the results of the budget process. The annual budget reflects our best effort to pursue a balanced and responsive program within the constraints of the available funds. While the 5-Year Plan provides a good source of planning data, it is necessary for us to translate that planning data into a realizable near term plan.

QUESTION E-25:

It is clear that Science should play a major role in the design and utilization of the Space Station.

a. How can you assure us that the development of related science projects proceeds at a vigorous pace in order to take optimum advantage of the Station? What is the ATD-type funding for the development of AXAF, SOT, GP-B, SIRTF, TOPEX, OPEN (or ISTP), and Mariner Mark II development in the FY 1985 budget?

ANSWER E-25:

The Science and Applications community is well represented in space station studies and it is recognized that the ability to make use of the space station will be driven by both the resources available to acquire space station science investigations and the capability of the space station to accommodate such science at a reasonable cost to the user. The required resources available for new space station science will be identified as the specific experiment and instrumentation plans are developed over the next two years. It is likely that there will then be a series of trade-offs for resources, balancing requests for new space station science, use of wedges developing as the currently planned science program of the 1980's is completed and considerations of moving currently planned science to the space station.

Current definition funding planned: ($ in millions)

AXAF	8.0
SOT	Not Applicable-Project beyond ATD phase
GP-B	5.0
SIRTF	1-2
TOPEX	4-6
ISTP	1-3
Mariner Mark II	1

QUESTION E-26:

The TOPEX and NROSS missions which are now in planning appear to offer the potential to gain a great deal of new knowledge about the circulation and physical characteristics of the ocean.

a. How has NASA involved the oceanographic community in the mission planning and data analysis?

b. What role would you envision for other agencies such as the National Science Foundation and the National Oceanic and Atmospheric Administration in making coordinated measurements?

ANSWER E-26:

a. NASA has involved the ocean science community in mission planning for both TOPEX and the scatterometer proposed to fly on the Navy's NROSS satellite since the inception of both projects. For example, a broadly based Science Working Group chaired by Dr. Carl Wunsch of MIT was formed in early 1980, when initiation of concept definition studies on TOPEX began. Based on the published science requirements, NASA developed a mission design for TOPEX and continues to work hand-in-hand with the oceanographic community on TOPEX. A similar process has been followed for NASA's NROSS scatterometer (NSCATT). Looking beyond aspects that deal with mission design to specific science requirements, both TOPEX and NSCATT have been made responsive to the broader oceanographic requirements as defined in recent reports of both the National Academy of Sciences' Space Science and Ocean Science Boards and the Committee for Climate Change and the Ocean (organizationally falling under the Intergovernmental Oceanographic Commission and Scientific Committee for Oceanographic Research) in coordinating NASA plans with two major international ocean field programs (World Ocean Circulation Experiment (WOCE) and Tropical Oceans/Global Atmosphere (TOGA)) that critically require data of the type that TOPEX and NSCATT would provide. In terms of interest on the part of the oceanographic community, many articles have been published and several special sessions dealing with oceanography from space, with emphasis on TOPEX and NSCATT, have been held at major scientific conferences. In addition, the Joint Oceanographic Institutions, Incorporated (JOI)--an organization of the ten academic institutions that maintain deep-sea going ships--is preparing a ten-year plan for oceanography that clearly relates proposed NASA flight projects to the needs of the research programs, such as WOCE and TOGA, planned for the next decade.
Finally, NASA plans to release an Announcement of Opportunity this summer to solicit proposals from the worldwide oceanographic community for the purpose, not only of utilizing TOPEX and NSCATT data to address critical oceanographic science questions, but also to provide assistance to NASA during the pre-launch implementation time period.

b. Preparations for two large international ocean experiments planned for the next decade--WOCE and TOGA--are underway with NSF and NOAA, respectively, taking the lead role for the U.S. components. The overall goal will be to understand the ocean's role in climate variability. While NSF and NOAA will support the bulk of the at-sea traditional observations, NASA will contribute the requisite spaceborne observations--altimeter data from TOPEX and scatterometer data from NSCATT for the determination of surface currents and winds, respectively.

Last May NASA's Administrator met with NOAA Administrator Byrne, NSF Director Knapp, and Assistant Secretary of the Navy Paisley to discuss continuing cooperation in spaceborne oceanography. At this meeting, NSF Director Knapp clearly indicated this desire to encourage NSF investigators to utilize spaceborne observations of the ocean to complement traditional oceanographic techniques. An excellent example of the cooperative activities discussed was the provision by NASA of a scatterometer for flight on the Navy's NROSS. Such an arrangement is an extremely cost effective way to satisfy both NASA research and Navy operational objectives.

NASA for many years has worked with Navy, NOAA, and the Defense Mapping Agency (DMA) to provide high quality altimetric measurements of ocean surface topography for both geodetic and oceanographic purposes. Accordingly, NASA is looking to DMA for precision tracking support for TOPEX, to Navy and NOAA for precision orbit determination support, and to NOAA for assistance in calibrating TOPEX's altimeter.

QUESTION E-27:

The FY 1985 budget contains a new start for UARS.

a. Why has the system been reduced from a two satellite system as originally planned to a one satellite system? What will be the difference in the science return? Cost?

b. Can you describe plans for data management and data dissemination? Is UARS unique in its data management needs?

ANSWER E-27:

a. The fundamental reason for reducing the program from a two satellite system as originally planned to a one satellite system was to reduce total program cost. By eliminating the second satellite, the second complement of instruments, and those parts of the Ground Data Handling System related to operations and data processing associated with the second satellite, the estimated cost of the program was reduced by 35-40%.

Certain science descoping also resulted as part of this overall program descoping. The total duration of the mission, and thus the available science observation time, was reduced from 30 to 18 months. This resulted in reducing the observation goal from three northern hemisphere winters to two. In addition, the remaining single orbit, selected to be 57°, resulted in the elimination of the ability to make direct observations of the poles. Finally, direct science observations of the mesosphere and the thermosphere were de-emphasized as mission requirements.

In summary, UARS science observations were deliberately descoped and thus limited to that set considered to be essential to acquiring the core knowledge necessary to accomplish the objectives of the upper atmosphere research mission. Desirable, but not mandatory measurement "requirements" were dropped. Stated another way, this programmatic descoping activity, to reduce total program cost, did not result in reductions in the core measurements capabilities considered to be fundamental to the accomplishment of the UARS mission. This core set of requirements was not compromised.

b. The basic science philosophy of the UARS project requires that the UARS system provide a means for conducting a long term, in-depth investigation of the upper atmosphere, with the widest possible direct involvement of the user science community. In implementing this philosophy, the UARS system comprises a single large scale comprehensive experiment.

The UARS Ground Data Handling System consists of two major elements: a Central Data Handling Facility, located at Goddard Space Flight Center; and a complement of remote, interactive data terminals,

located at the principal and theoretical investigators' "home" locations, which provide these investigators with timely, highly-interactive access to data.

The key feature of the system is that all data from all instruments will be available in the Central Data Handling Facility (CDHF) for interactive utilization by all investigators. Science algorithms will be developed by the individual investigator, and certain of these algorithms will then be placed in operation in the CDHF. Following the initial Ground Data Handling System post launch "shakedown" period (approximately the first six months after launch), it is expected that each day's acquired science data will be available on-line for the investigators' use within 24 hours of acquisition. The more detailed levels of science algorithm development, and detailed science analysis of data is also the responsibility of the individual investigators and their science teams.

In implementing the data management philosophy, the UARS program builds on the experience gained from the Nimbus, SME, AE, and DE programs. The UARS data acquisition system thus will be unique in its approach to maximization of the timeliness and interactiveness of the processed data, and in implementation of a system permitting the widest practical, timely dissemination of processed data to the user science community.

QUESTION E-28:

NASA has also described a potential new start in its 5 year plan called OPEN (Origin of Plasmas in the Near-Earth Neighborhood).

a. Inasmuch as it would seem to provide valuable data on sun-earth interaction, can you plan for both UARS and OPEN to collect data in a coordinated fashion?

b. What additional science objective might be met by such a coordinated measurement program?

c. Has your goal of securing international cooperation for OPEN delayed its start?

ANSWER E-28:

a. Both of the Central Data Handling Facilities for UARS and OPEN (now ISTP) would be located at the Goddard Space Flight Center. It is planned that these two facilities will be tied together in order to share computer resources and to enable convenient data correlation. Also both Control Centers will be located at GSFC so coordinated observing programs can be conveniently carried out. In addition, it is anticipated that the UARS and ISTP investigators will be networked together.

b. ISTP will be able to provide detailed information on solar flares and longer term solar surface trends so that UARS could be operated in special modes to observe the atmospheric responses. ISTP also provides detailed measurements of the visible, ultraviolet, and energetic particle input to the atmosphere with detailed maps of particle energy deposition extracted from the Visible, ultraviolet and X-ray images of the ionosphere/upper atmosphere. With the planned

commonality in the structure of the UARS and ISTP data bases it should be easy to carry out cause-effect analyses.

c. No, in fact the negotiations for international participation have raised the visibility and interest of the ISTP mission.

QUESTION E-29:

What steps has NASA taken, or will it take, to improve coordination with the NSF in the space science area? Would NASA's effectiveness in carrying out its space science missions be enhanced by a "lead agency" designation for space science?

ANSWER E-29:

Over the years NASA, in carrying out its space science program, has had extremely close coordination with the National Science Foundation. For example, there are regularly scheduled coordination meetings between the Office of Space Science and Applications staff and the staff of the various divisions in the Directorate for Astronomical, Atmospheric, Earth, and Ocean Sciences at the Foundation. Even more important are the frequent individual contacts between the staff at both agencies responsible for various areas of the program. We believe there is an excellent working relationship between NASA and the Foundation, and the most important step to be taken is to make sure that the existing relationship is maintained.

Reference to the language in the National Aeronautics and Space Act of 1958 would suggest that NASA has, in fact, already been designated as the "lead agency" in space science.

QUESTION E-30:

The budget for the solid earth observations program seems to be shrinking. Also, as described in testimony, it sounds very similar in goals to the Environmental Observation program. What is the difference between the Solid Earth and Environmental programs and is the Solid Earth program being phased out?

ANSWER E-30:

NASA's solid Earth observations program has been merged with the environmental observation program into a more comprehensive program under the auspices of Earth Science and Applications. We hope that this merger will lead to greater interaction between researchers involved in studies of the solid Earth and its environment, and greater emphasis upon the use of remote sensing technology in addressing important scientific and long-term applications problems of an interdisciplinary nature. Past research in solid Earth observations has been largely concerned with the practical short-term applications of remote sensing techniques (e.g., crop assessment and forecasting, mineral exploration, water resource management, etc.). These earlier programs have raised concerns that the Federal Government is actually conducting tasks that should more properly be conducted in the private sector or by the user agency. The current reduction in funding for our solid Earth observation research activities has resulted from the termination of some of these earlier short-term applications programs. At the present time we are

reorienting our solid Earth program to address a series of more basic scientific and long-term application questions related to surface conditions on our planet (e.g., biomass production, decertification, and the biogeochemical cycling of selected elements).

QUESTION 31:

a. Are there practical applications of the study of Solar-Terrestrial Physics?

b. Have there been recommendations from your advisory committees that NASA have a division of Solar Terrestrial Physics? What are they?

c. How have you responded to these recommendations? Are all STP activities localized now?

ANSWER E-31:

a. Certainly there are very significant physical and chemical ties between the Sun and the Earth. Solar outputs (light energy, solar magnetic fields and solar particles) provide daylight, establish the equilibrium temperature, drive wind, water and biological systems, distort the geomagnetic field and create aurora. Although all of the detailed Sun-Earth interactions are not fully understood, the correlation between the solar magnetic/sunspot 11 and 22-year cycles and the terrestrial drought periods must be more than circumstantial, for example. With understanding of these interaction processes at least we should be better able to predict the long term climate and possibly the weather and to protect the biosphere/atmosphere system. On the practical side, predictions of magnetic disturbances based on solar activity are made regularly for warning of surges in power systems, disruption of long range communications both via telephone lines and radio links, operation of over the horizon radar, misleading magnetic field readings taken by geological survey crews and for prediction of pipeline corrosion.

b. Within the past year, there have not been any formal recommendations from the NASA/Space and Earth Science Advisory Committee or the National Academy/Space Science Board, Committee on Solar and Space Physics or Committee on Solar-Terrestrial Research, that a Solar-Terrestrial Physics Division be re-formed. However, suggestions have been made by a number of individual scientists and several groups of scientists.

c. At present there is a Solar and Heliospheric Physics Branch in the Astrophysics Division and a Space Plasma Physics Branch in the Earth Science and Applications Division within Space Science and Applications. The solar-terrestrial research is coordinated between these two branches in treating solar-terrestrial topics whereas the Solar Branch also handles topics that treat the Sun as a star. These two branches are working together to formulate the International Solar-Terrestrial Physics Program. In terms of ISTP, the Space Plasma Physics Branch Chief acts as the coordinator and NASA spokesman. In the Earth Science and Applications Division, coordination with the other branches (Upper Atmosphere, Land, Oceans, Geodynamics) is easily carried out.

QUESTION 32:

NASA is restructuring its main solar-terrestrial physics flight program, OPEN, into a cooperative international program called ISTP.

a. The NASA OPEN Program has been proposed as a cooperative program for the Solar System Exploration Initiative endorsed at the Williamsburg economic summit meeting. What is the status of the OPEN program within NASA?

b. NASA has recently held bilateral and trilateral meetings with the Japanese/ISAS and the European/ESA to create the International Solar-Terrestrial Physics (ISTP) Program. What committments has NASA made to these potential partners?

c. When does NASA plan to start the ISTP program?

d. For the ISTP program, what steps are being taken to avoid the embarassment of the International Solar Polar Mission (ISPM) situation, where NASA reneged on its commitment halfway through the program?

ANSWER E-32:

a. ESA of Europe, ISAS of Japan and NASA have conducted two rounds of tri-lateral meetings and associated bi-lateral meetings on both the scientific and programmatic levels to establish the framework of ISTP of which major elements of the OPEN Program are included. A draft agreement to formally establish a Joint Planning Group has been prepared for agency signature before June 1984. NASA is presently considering ISTP's potential as a new start candidate; ISAS is preparing to initiate activities in FY 85 (April 1985) and ESA is conducting Phase A studies of both SOHO and CLUSTER pointing toward a mid-1985 decision to commit to development.

b. In the recent Tri-lateral meetings, NASA has made no formal commitments to either ISAS or ESA. A draft MOU has been sent to ISAS for comment but it would not be signed until after April 1985. In the tri-lateral agreement to be signed before June 1984, each agency agrees to plan together toward the ISTP Program and to make a best effort to secure agency approval consistent with the proposed schedule.

c. Planning for the ISTP program is presently underway as exhibited by the meetings conducted with the Europeans and the Japanese. The ISTP mission should be ready for consideration as a possible new start within the next two or three years.

d. Since NASA defends its budget to Congress on a year-by-year basis and the budget is established yearly, NASA cannot commit the U.S. Government to complete a cooperative project. The possibility that the U.S. may have to back out at some future date always exists. However, NASA will carefully plan for the resources required each year and will apply good management techniques to keep the program on schedule and within cost. Each MOU will probably contain agreements that each side will consult the partner whenever a situation exists that could cause delay or cancellation of the program.

QUESTION E-33

The science community seems to be dissatisfied with the opportunities to carry out scientific and technical investigations using the Space Shuttle.

a. What are the main specific complaints?

b. What specific responses are you making to these complaints?

c. Does the divided responsibility for Spacelab (between OSSA and the Shuttle office) contribute to problems?

d. What lessons have you learned that can be applied to Space Station?

e. How will NASA avoid the widespread perception that future science must be forced into a format and protocol compatible with a space station?

f. It is clear that the postponement of STS-9 and the later flight at a non-optimum time for the science experiments revealed the critical tradeoffs that must be made between science return objectives for a single platform concept. Does this not suggest that the selection of a Space Station concept will, by definition, preclude some areas of space science? How will you determine the priority of, for example, stellar UV astronomy vs. solar astronomy?

ANSWER E-33:

a. The main specific complaints are:

- The number of flight opportunities
- The length of time between flight opportunities.
- The length of time involved in preparing for any specific mission
- The funding available for new science instruments.

b. NASA added additional flight opportunities to the extent the flight manifest, the funding levels, and science and technology requirements will allow.

We are implementing the concept of dedicated discipline laboratories which we plan to refly on 1-2 year centers by keeping the hardware elements integrated to the extent possible. This reduces our planning and integration costs, allowing funding for other missions and minimizes turn-around time between missions.

In addition, we are trying to decouple instrument development from the specific mission planning activities to the extent practical to shorten the mission planning cycle and to allow the instrument developer/principal investigator to minimize his interaction and time on the specific mission.

c. NASA has felt that the Spacelab can be best served by being considered to be a part of the Shuttle as opposed to an element of cargo. It has always been clear that, due to the complexity of placing of payloads aboard the Shuttle, some engineering element is

necessary to offload the users from a number of tasks necessary to place experiments on the Shuttle but not directly pertinent to the actual construction of the instruments. The respective organizations (OSSA and OSF) have held, from time to time, discussions about merging the two activities. However, due to numerous joint activities, to accomplish the Spacelab program-wide studies, a continued responsible level of performance has been achieved. No major duplication or excesses have been identified. Thus, the factors which motivate one to join the two organizations are sufficiently low that they do not overcome the perturbations which might be caused by a merger.

d. We have learned valuable lessons in managing the development of instruments, methods of interacting with principal investigators for flight projects developed in parallel with carrier systems, and techniques for managing flight projects involving large numbers of instruments/investigators, methods to minimize time and costs in integration of multiple instruments and experiments onto a single carrier. As part of the Spacelab 1 effort we have gained experience in the interactions of ground and flight crews during a mission to maximize science return, science synergisms and instrument trouble shooting and repair.

In addition, we have learned lessons in understanding science and technology flight data flows and requirements, and in shortening the time from data acquisition until delivery of data to the principal investigator.

We have gained experience in selecting, training and flying scientists. The science return has increased because these unique Science Payload Specialists are able to become surrogate P.I.'s, extending the P.I. laboratories into space.

We have also learned how to establish, manage, and operate with multi center organizations in the performance/conduct of single missions. We have in place strong, team oriented organizations supporting each Spacelab mission.

e. We plan to encourage and promote the use of distributive systems such as command and control, data acquisition and formating which will allow individual instruments to be relatively independent of space station centralized systems. This will allow the investigator more independence and autonomy in conducting his science, application or technology experiments. It will also allow him to be able to take advantage of the latest technology developments as they are created without impacting other investigators or station systems/sub-systems.

f. With Space Station operations on a continuous cycle, we can preclude many of the conflicting requirements imposed on Spacelab 1. We will always have opportunities at optimum times for either stellar ultraviolet astronomy or solar astronomy. We plan to support both science disciplines on a non-interference basis. Even though we will be on a single platform, the attachment of multiple instrument carriers onto the platform for each compatible science discipline will preclude most science conflicts which would require prioritization.

QUESTION E-34:

ESA and NASA have invested heavily in Spacelab hardware and facilities for the Shuttle. The Spacelab 1 mission has been very successful. Looking at the Shuttle manifest after Spacelab 4, there are few dedicated Spacelab flights. What are OSSA's plans for utilizing Spacelab?

ANSWER E-34:

Spacelab hardware was designed with the thought that it could be utilized in a number of different configurations, i.e., short versus long module and as many as four pallets. The trend in planning after Spacelab 4 has been to go for mixed-cargo flights thus obtaining some revenue from each flight. Consequently, missions using Spacelab elements, based on the January 1984 manifest are as follows:

Flight No.	Payload Name	Configuration
61-F	Astro-1	Igloo, 2 Pallets, IPS
62-B	OSTA-5	1 Pallet
61-K	Sunlab-1	Igloo, Pallet, IPS
71-D	Astro-2	Igloo, 2 Pallets, IPS
71-E	EOM-2	Igloo, Pallet
71-J	D-4 (German)	Igloo, 4 Pallets
72-A	OSTA-7	Pallet
71-M	IML-1	Long Module, Pallet
71-O	Astro-3	Igloo, 2 Pallets, IPS
71-S	Sunlab-2	Igloo, Pallet, IPS
81-C	EOM-3	Igloo, Pallet
82-B	OSTA-9	Pallet
81-G	Spacelab-J	Long Module, Pallet
81-I	SHEAL-1	Igloo, 2 Pallets
82-C	Space Plasma Lab-1	Igloo, Pallet
81-O	Life Science Lab-3	Long Module

QUESTION E-35:

NASA has proposed a joint project with Canada and industry to demonstrate technology for using satellites for land-mobile communications.

a. Exactly what is the proposed Mobile satellite project:

b. Has this project been restructured from an earlier proposal?

c. What do you need from the FCC for this program?

ANSWER E-35:

a. The NASA program, to enable commercial mobile satellite service and develop the technology needed for growth, is being implemented through a joint endeavor agreement with U.S. industry. Close cooperation is being maintained with the Department of Communcations (DOC) in Canada whose role is similar to NASA's. The U.S. entity or carrier would provide a small portion of the satellite's channel capacity to NASA for second generation terminal hardwre validation and other government agency experiments. NASA anticipates providing standard shuttle launch services at no cost to the selected firm. The

carrier would utilize the additional satellite capacity to develop commercial markets. The U.S. carrier, with its Canadian counterpart, would specify, procure, own, and operate the space segment, and obtain the necessary frequencies and licensing approval from their respective regulatory organizations. Thus, commercial and experimental capability will be provided on the same spacecraft.

b. Yes, the program has been restructured. The earlier program was based on a cooperative venture with DOC where Canada would have built the spacecraft and provided channel capacity for NASA experiments in return for shuttle launch service. With the emergence of interest in mobile satellite service by U.S. industry, this program was restructured to favor U.S. industry as described in paragraph (a). NASA and DOC are continuing to coordinate their activities to involve the private sector in both countries since the technical nature of this system and the realities of WARC '79 require such cooperation.

c. We need help from the FCC in structuring our joint agreement with industry in a manner that satisfies our technical requirements and is at the same time compatible with FCC's regulatory licensing process. In addition, the FCC needs to go forward with its rulemaking process and allocate the frequencies required by industry to implement this new service in an expeditious manner.

QUESTION E-36:

Have Goddard or JPL been asked to play an institutional, high-level role in planning the station in order to assure that the station is compatible with science and applications needs?

ANSWER E-36:

Yes, it has been proposed that both GSFC and JPL act as the organizations which will interface and represent all user communities.

Discussions on this subject were held between the Associate Administrator for Space Science and Applications and the GSFC and JPL Directors.

QUESTION E-37:

We understand that NASA has established a new advisory committee for the scientific use of the space station.

a. Since this committee will only make input to another advisory committee, the Space and Earth Sciences Advisory Committee, which reports to an associate administrator having no direct authority over space station planning, how can this new entity have any effective role in the design and implementation of the station?

b. What is the relationship between this new advisory committee and the Space Station Task Force under John Hodge?

c. What other sources of scientific input will space station planners have?

ANSWER E-37:

a. This group's inputs will be taken very seriously as the science community will be a major user of the Space Station and the four Science and Applicationns personnel are actively involved in the Space Station planning.

b. This committee has been charged by Dr. Edelson to review space station planning to assure maximum possible sensitivity to the needs of the science and applications user community. The committee does report to the NASA Advisory Council and can provide input to the Space Station requirements through the highest level of NASA.

c. The Office of Space Science and Applications has been developing requirements for the space station through each of the discipline divisions (Astrophysics, Microgravity, etc.). These divisions have been working with their respective science communities and the NASA Centers to develop space station utilization strategies.

QUESTION 38:

a. At last year's hearings NASA indicated that the start-up of SOT would be deferred until the space telescope was out of trouble at Perkin-Elmer. What are your current plans for moving forward with SOT? What funding is in the budget for SOT?

b. What is the impact of delaying the start-up of SOT on its run-out cost and launch schedule?

c. Will the delay in moving forward with SOT impact the completion of ST at Perkin-Elmer?

ANSWER E-38:

a. We plan to move forward with SOT in an orderly fashion. NASA established an independent ad hoc Working Group of senior technical managers and scientists to review the SOT program technical and functional approach.That group took no exception with the planned approach. Some useful suggestions regarding objectives were made and are being incorporated in the program. Our current plans assume a level of $8-10M for SOT in FY 1985. Assuming continued progress on the Space Telescope, we will be in a position later this year to determine the actual 1985 funding on SOT.

b. A cost review has not yet been conducted on SOT. However, our best estimate of the SOT runout is $250-300 million which assumes a start in the FY 85/86 timeframe.

c. The development of SOT as currently planned will not impact the completion of the Space Telescope. Our plan is not to increase the effort on SOT until after the Optical Telescope Assembly is delivered to Lockheed, thereby averting any possible impact on the Space Telescope.

Mr. VOLKMER. Thank you very much, Dr. Edelson.

I have a few general questions first. I would like to start off on one before I forget and that is on what I call large ticket items, the space telescope, Venus radar mapper, GRO, et cetera. I would appreciate if you could furnish us—I don't anticipate that you could do it today, but within a week—a runout on the costs on those ticket items. In other words, we know what 1985 is, but 1986, 1987, 1988, or however long they go, what is the anticipated costs in those years on those items?

Dr. EDELSON. I would be glad to do that, sir.

[The information follow:]

OFFICE OF SPACE SCIENCE AND APPLICATIONS—FISCAL YEAR 1985 BUDGET ASSUMED RUNOUT
MAJOR FLIGHT PROGRAMS

	Prior years	Fiscal year—		BTC	Estimated cost at comp. section
		1984	1985		
Space telescope development	652.7	195.6	195.0	131.7	1175.0
Gamma ray observation	50.7	86.2	120.2	168–218	425–475
Galileo	486.2	79.5	56.1	208–288	830–910
VRM		29.0	92.5	228–278	350–400
MGCO			16.0	284–359	300–375
UARS	20.0	20.0	60.7	529–599	630–700

Mr. VOLKMER. In your general statements concerning the mission and objectives of the space science and applications program, you indicate the intent is to advance our knowledge of Earth, the Sun, the planets, et cetera. Do you see the mission as truly a mandate to advance our knowledge in general or rather to support those efforts most compatible with the space hardware developed by NASA?

Dr. EDELSON. Mr. Chairman, I think that we have a mission to explore and to perform scientific research in those various areas, in astrophysics, and planetary exploration, and in Earth science, using the vantage point of space and the synoptic view that we have, the view of the heavens from above the atmosphere and using the capabilities that NASA has, but it should be the science and the applications leading the technology, if I gather the sense of your question, rather than the other way around.

Mr. VOLKMER. I agree with that, but how does that then relate to such things as the shuttle and eventually, maybe, the space station? What I am trying to get to is that there is some concern, I know, that some of the science community has that those scientific experiments that are going to take place in the future will probably have to utilize those flight operations, either the shuttle or the utilization of the space station.

Do you agree that that is going to be what is going to happen in the future or do you agree that we will still have scientific experimentation, either planetary or the solar or what, that will not have to utilize the space shuttle or the space station?

Dr. EDELSON. That is a good question, Mr. Chairman. I think the answer is that we have the mission to do the science. Where appropriate and cost effective, we should use the space facilities capabil-

ity that NASA has. More specifically, I think that there will always be a dedicated spacecraft and that we will have missions independent of the shuttle and the space station, the obvious example being the planetary exploration missions and others like solar terrestrial physics and so on.

Mr. VOLKMER. In other words, those things that are appropriate would utilize the vehicles of NASA, but where it is inappropriate they would not neccessarily have to.

Dr. EDELSON. Yes, and we will study that and compare that and try to do that.

Mr. VOLKMER. All right. On the ACTS program, as I understand it, we are going to continue with ground-based research on the new technology. As you testified, the program to go ahead with a flight test is out of the budget right now. Will it ever get back in the budget?

Dr. EDELSON. Our present plan, Mr. Chairman, is to conduct a ground-based test program. We are developing a very good program of ground testing. This involves assembling the technology and subjecting it to test and simulation on the ground. The money that we have in the 1985 budget, $5 million, coupled with the money already in 1983 and 1984 funds, will be used for ground test. We have no plans for a flight test.

Mr. VOLKMER. That is never? That is what you are telling me? Are you satisfied that the ground testing will be sufficient to test out the technology?

Dr. EDELSON. I would say this: the ground test program will test some of the technologies very, very well and will perform a good test of the very important technologies in the ACTS program.

Mr. VOLKMER. There are differences, are there not, between the proposed Hughes satellite and the proposal on the ACTS program, the technology there?

Dr. EDELSON. Yes, there are very significant differences between what Hughes has filed for and the ACTS technology.

Mr. VOLKMER. Then, why are we then saying we are not going to flight test? What is the reasoning behind that?

Dr. EDELSON. We feel that if commercial endeavors are active in the field, developing and flying the technology that they think is appropriate for the maketplace, it is not necessary for NASA to do a flight of that technology although we feel that is very necessary to develop and test the technology on the ground so that commercial entities may use it and fly it in operational satellites when the marketplace demands are such as to require it.

Mr. VOLKMER. Then, are we saying to the, as I understand it, the contractor that was with the ACTS program that even though were they not told that there would be a go-ahead with the flight test?

Dr. EDELSON. Yes, we told that contractor. The contractor is RCA. We issued an RFP. A team led by RCA turned in a responsive proposal and we were negotiating, in fact, I think we had completed negotiating the contract, but we had not signed it, and we have told RCA and other contractors involved that we are changing our program now to be a ground test program.

Mr. VOLKMER. As I understand, the old ACTS program was to upgrade the communication systems in the higher band. Is that correct?

Dr. EDELSON. Well, really more than that, Mr. Chairman. The purpose of the ACTS program was and still is to maintain and in some instances regain U.S. technological leadership in satellite communications technology. Those technologies fall into a number of categories. One of them is the radio frequency, the microwave technology, the use of the 30-20 Ghz band, but there are other technologies, the antenna technology, switching technology, and the processing technology, that are of great importance. These technologies, particularly the latter ones, are those that we can test on the ground.

Mr. VOLKMER. What I hear is, maybe I am wrong and I want you to correct me if I am, that the R&D that is permitting Hughes to proceed with their satellite, and therefore the private R&D, is sufficient there, but it is not quite sufficient because we are going to do ground testing. There are areas, as I understand it, such as switching and processing, that are in the ACTS program and are not necessarily in the Hughes program——

Dr. EDELSON. That is correct.

Mr. VOLKMER. Yet, we don't think it is appropriate to flight test this equipment. To me, I just can't understand—to prove it out, and why. You maintain that we can do it here on Earth. We can pretty well test it out. But is that going to be good enough for anybody who wants to utilize it in the future?

Dr. EDELSON. That is a value judgment, Mr. Chairman. I think I can clarify a few points. One is that the technology which Hughes and others, incidentally, plan to fly in the later part of this decade will be based on present technology or a slight extrapolation of that technology to push into higher capacity, more effective satellite communications. Our observation is that the United States is not so clearly leading in these technologies, that there is a major effort in Japan and in European countries which, in some cases, has put us in the United States and the U.S. industries somewhat behind in those important technologies, switching and processing. The ACTS program is aimed at coming up with a whole new set of technologies which are yet to be developed and tested, aimed at the marketplace of the middle 1990's.

We feel that it is essential to develop those technologies and to test them to a certain extent. It is our judgment that the major benefit, at least for the next few years, will be to develop the technologies and to test them in a simulation system, a so-called testbed, which simulates the performance of the satellite transponder, the radio links to the ground, and the Earth station RF and synchronizing equipment. We feel that that is a very valuable program and an adequate program, and we are formulating—we believe we have enough money in 1983, 1984, and 1985 to do that—and we are formulating a program over the next few years to make a complete test of those technologies to the extent that we can do it on the ground.

Mr. VOLKMER. What changed the mind between the necessity last year of flight test and this year we don't need a flight test?

Dr. EDELSON. The commercial activity in this field and, particularly, the Hughes filing.

Mr. VOLKMER. Does that lead me to believe, then, that we no longer need to have NASA involved in communication research and development, that we can leave it to the private sector?

Dr. EDELSON. No, sir. I would not wish to leave that impression in your mind or in the mind of anyone present. We feel that it is extremely important for the Government, in this case, NASA, to push in this important technological field. The difference of opinion that is about has to do with the necessity of a flight demonstration of this technology as opposed to the development and ground testing of it.

Mr. VOLKMER. I am going to permit the gentleman from New Mexico, but I would like to close and to say that perhaps some other time we can have a little more time to discuss whether the ground testing is sufficient or not. That is the thing that concerns me. I have used up my time now. I will come back a little later on some other areas of the budget where I still have concerns if they don't get to it.

I recognize the gentleman from New Mexico.

Mr. LUJAN. Thank you, Mr. Chairman.

Dr. Edelson, I am not sure if it was yesterday, or Friday, or when it was, that we had hearings in one of the other subcommittees at which Dr. Ed Knapp of the National Science Foundation was testifying, and he spoke about the very large baseline radio telescope. I am not quite sure how that differs from what information we are going to get from the space telescope. Can you tell me?

Dr. EDELSON. Yes, they are quite different in general. If I may be permitted, I would like my colleague, Dr. Rosendhal, to address that program specifically.

Dr. ROSENDHAL. Yes, the space telescope, as you may know, is largely an optical telescope.

Mr. LUJAN. While you are doing that, there is the other one that they have over there and it is a part of the very large array, very large baseline array, and the space telescope. If you would put those three in perspective for me, I would appreciate it.

Dr. ROSENDHAL. OK. In one case, we have an optical telescope which looks at objects such as stars, moderate temperature objects, the atomic universe, as it were, the light emitted by atoms which reveal physical conditions in the various objects that we see.

In the case of a radio telescope, one in general looks at a different set of physical processes, whether it is the VLA or the VLBA, one looks at the effects of things such as high energy electrons or the influences of magnetic fields. One looks at structures and objects, a different set of physical processes than you do in the case of the optical objects that you see with the space telescope.

Now, in particular, in the case of the VLA and the VLBA, what you want to do is look at the very fine details in those objects. The objective of any array of radio telescopes is to look at very small scale structures. Radio wavelengths are quite long. In order to look at the detail, you need something that is the equivalent of a very large aperture system. One way of getting the equivalence of a very large aperture system is to do what is called synthesis of the aperture, and that is what you use an array for, to simulate the resolution which is achievable by a very large radio telescope. In the case of the VLA or the VLBA, something that might be miles

in extent in the VLA, or thousands of miles in the case of the VLBA.

Mr. LUJAN. What is the difference between the VLA and the VLBA?

Dr. ROSENDHAL. Scale, detail.

Mr. LUJAN. They are going to be doing the same job?

Dr. ROSENDHAL. No; well, basically the VLA could be regarded as a precursor telescope to the VLBA.

Mr. LUJAN. Well, following on that, we have had all kinds of problems with the space telescope, but I guess we are back on the track with it. You anticipate that that is going to move along fine? What does it do to us timewise from, maybe, the point where we began and where we are at the present time and on into the future?

Dr. EDELSON. I would like the opportunity to ask Mr. Sam Keller to say a few words on that. I think that he can summarize very succinctly the problems that we were facing and the progress that we have made recently and the outlook on the space telescope since he has been devoting a lot of his time to it.

Mr. LUJAN. I think we are rather familiar with what the problems specifically were. I would be more interested in, and that is only because of my 5 minutes—the chairman has graciously granted me a little more time——

Mr. KELLER. Mr. Lujan, let me give you a very quick answer to that question, and then I will respond later if anybody wants details.

As you know, we did go through a basic major overhaul of the telescope program in the last year. Right now, we are scheduled to deliver the optical telescope assembly from Perkin Elmer on the 1st of November of this calendar year. That is a schedule we set last May. At this point in time, I expect that delivery to occur at that point in time.

We are working toward a launch readiness of May, or actually April 1986, with a launch date in the summer of 1986, and while I think because of the time there is a little more risk involved there, I see no reason why we won't make that date.

Perkin Elmer has two elements in their schedule about 10 or 12 days behind schedule right now. Lockheed has some electronic boxes about 3 weeks behind schedule. Other than that, we are on the schedule we established last year. Our costs will be tight this year, but we expect to be within the envelope, and we have compromised none of the original scientific objectives.

So, while we often describe it as a thrill a week, it is not one we can relax on. We have a lot of problems, but we seem to be solving them at about the same rate they crop up. So, it will be tough, but we expect to be there.

Mr. LUJAN. We have moved, then, from the space telescope program to this solar optical telescope. Is it that with the solar optical telescope we are just going to look at the Sun and with the other one we are going to look at a lot more things? Is that basically the difference?

Dr. EDELSON. To the first approximation, yes, Mr. Lujan. It is a specialized instrument for studying the solar dynamics.

Mr. LUJAN. One final question. In going over your written testimony which you have submitted and in which you talk about the space station, I have been concerned that we will get some attacks on the space station, don't spend the money for that because that is going to take money away from the sciences and those sorts of things. In reading almost toward the conclusion of your statement, you anticipate studying possible space science and applications utilizations of both the manned and the unmanned elements of the space station. However, further on you say, "we are particularly interested in the space station coorbiting platform for astronomical missions and polar orbiting platform for Earth observation missions." It looks like you are more interested in the unmanned portion of the space station rather than the manned. Do I gather that correctly from reading your statement?

Dr. EDELSON. The scope of science and applications covers a lot of different missions. For some missions, for example, astrophysics, we are interested in the instruments that will go on the unmanned platform, the so-called coorbiting or astrophysics platform, an unmanned platform that flies with and close to the space station and is serviced by the space station.

So, this gives us the best of both worlds. We have the isolation from attitude control problem and vibration and contamination that are inherent in man's presence, and yet we have the capability of servicing an assembly. For example, infrared imagery requires a cooling down to a few degrees K, and requires cryogenic fluid to be resupplied every few months or possibly as long as a year or so. The manned space station will be available to resupply it.

Also, many instruments, the space telescope is a good example, wish to change focal plane instruments, and the manned space station will be available to do that. In case of a problem, as we hope to demonstrate on the next shuttle mission, man in space will be able to repair spacecraft in orbit.

So, let me summarize our interest by saying that we feel that we will use, for many disciplines in science and applications, the manned space station itself, particularly in microgravity science and life science areas. We will use the platforms for many areas, but particularly astrophysics and Earth observations, and we will use the manned capability of the space station to service, assemble, check out, test, construct major new missions.

Mr. LUJAN. You do not consider applications of space science like manufacturing, those kinds of activities?

Dr. EDELSON. We rather differentiate between the budget line item called applications which has historical and those items which have or are expected to have practical applications. When we use the term applications in a generic sense, we are talking about communications, remote sensing, and materials processing in space which are or are expected to be of great practical benefit.

Mr. LUJAN. May I have 1 more minute?

Mr. VOLKMER. OK.

Mr. LUJAN. The various advantages, if you would, Dr. Edelson, on the space station, the shuttle, free flyers, from your research standpoint, there has got to be some tradeoffs in every one of those three areas. Can you give me the advantages, perhaps, that I might

be able to understand where we can do things better with each particular vehicle?

Dr. EDELSON. I think I can summarize pretty quickly. On the space shuttle, you have the advantage of economy and manned support. The disadvantage is that you are fairly well constrained to certain orbits which may or may not be desirable from a scientific or applications point of view. I think that is it right there.

The advantages in free flyers are that you get precisely the orbit that you want and you can launch precisely when you want under your control.

The advantage of the space shuttle and, we presume, the space station, is that you are attached to a larger program and you don't get your exact choice.

Mr. LUJAN. Thank you.

Thank you, Mr. Chairman.

Mr. VOLKMER. The chair now recognizes the gentleman from Virginia.

Mr. BATEMAN. Thank you, Mr. Chairman.

My recollection is that the next space shuttle mission includes the retrieval and repair of a satellite. Is that the Landsat 4 or is that some other satellite?

Dr. EDELSON. That is the Solar Max, solar maximum mission, a spacecraft put up in 1978—I am not sure of the date now—to observe the Sun during its maximum solar flare activity. That satellite failed in orbit. It failed in two ways. Its attitude control system failed so it is tumbling, and one of the scientific instruments, a coronagraph, failed.

We have established the case that would be extremely valuable to have that satellite back in orbit for scientific purposes. In other words, it is not a stunt. It is a very valuable and a cost-effective thing to do, so we are going up in the next mission to perform an extravehicular activity such as they are doing right now, but this time we will get this real failed satellite, bring it on board the space shuttle, fix both of those problems, and put it back in orbit.

Mr. BATEMAN. Could you just very briefly outline the factors that support the rationale of that being the first mission of that kind as opposed to making the Landsat 4 the first such rescue and repair mission.

Dr. EDELSON. The Landsat 4 hasn't failed completely yet. It is still operating. However, much more important and the answer I should have given first, is; that it is in a polar orbit, and we do not yet have a shuttle capability in polar orbit although we will by early 1986.

Mr. BATEMAN. Is there a factor that in the one instance you have a better fix on what is wrong with it and how to repair it than you do on the other, or does that enter into the equation as to which has the priority?

Dr. EDELSON. No, I don't believe there is a priority between them. Both Landsat 4 and Solar Max mission were built on the modular spacecraft basis and both of them were such that they could be repaired in orbit.

Mr. BATEMAN. Mr. Chairman, in view of the fact apparently we are going to discuss later the rationale and the basis for the change in NASA's plans with reference to the advanced communications

technology satellite flight testing or ground testing, I will leave questions on that to another day although it is an area that I think all of us on the committee are interested in.

Mr. VOLKMER. If the gentleman has any specific questions he would like to ask Dr. Edelson for the record, I think now would be an opportune time to do it. We don't have any other members here, so you are free to take the time if you wish.

Mr. BATEMAN. Well, I guess to give you the opportunity to educate me and the others on the record as to what is the rationale. If you could explore a little further the rationale of the changes, that is, NASA's plans and the manner in which it is impacted or the change in decision is impacted by the Hughes announcement.

Dr. EDELSON. I think to answer that question, let me call up our technical expert in that area, Robert Lovell, who can give you some in depth differences between.

I want to summarize that by saying that it was the Hughes filing that caused us to reconsider our program. We felt that it was a good program, but we had not taken into consideration the advance filings. With the advance filings and the statements of the community, this conflict in our thinking arose, and we felt that it would be important to go ahead with the ground testing program, and modified our program to do that so that there would not be this conflict between what industry wished and wanted to do to meet the marketplace and NASA's flight test which had, as a major purpose, a domonstrational aspect.

What we could go into if you desire, Mr. Chairman, is to outline some of the differences in the technology that are involved here.

Mr. BATEMAN. I guess basically what I am looking for is certainly not a quarrel with NASA about your not doing something if someone in the private sector wants to do it, expects to do it, and has the capability of doing it if, by virtue of your change of plans, we are not leaving undone things which in your original thinking were needed to be done. I suspect that I am probably going to get more answer here than I am able to understand, but basically, a conclusion is coming through that you have made, but I am not sure that I understand the rationale that supports the conclusion.

Dr. EDELSON. Let me start from the administration's policy and that of NASA and which I fully support. First, that the Government shouldn't use the taxpayers' money to do what industry will do. I think we all agree to that.

Mr. BATEMAN. Yes.

Dr. EDELSON. In this case, it is not an exact match, so the question evolves to whether the Government should use the taxpayers' money to do what industry——

Mr. BATEMAN. Leaves undone.

Dr. EDELSON. And, moreover, doesn't want the Government to do which is the case here.

Mr. BATEMAN. Well, as I understand that, there are aspects which you had otherwise planned to do that industry does not want done?

Dr. EDELSON. Well——

Mr. BATEMAN. Let me try it this way. I am getting a mental picture of because of what industry has announced it desires to do, it will accomplish enough of but not all the objectives that NASA had

in mind, but it accomplishes enough of them that it shifts your relative priorities, and therefore you have determined that in a better setting of priorities in light of that development, better you use your resources to do certain other things rather than to accomplish all the total objectives originally in mind. Is that a sound articulation of it?

Dr. EDELSON. That is a sound statement and well worded.

Mr. BATEMAN. Are there out there among people much more technically competent than I, and that is all the rest of the world probably, who disagree with your policy determination and feel that there is still a very high priority for what you originally had in mind that isn't going to be accomplished if you don't go forward.

Dr. EDELSON. Yes. I have been sensitive enough to what various segments of the industry are saying to know that there is a difference of opinion.

Mr. BATEMAN. Now, could you focus on what it is that some argue is going to be left undone and the importance of it being—not conceding they are right—but just try to express what that point of view is?

Dr. EDELSON. Let me step back and say that as far as I know, there is unanimous opinion that NASA should go ahead with the technology and the ground test. We assert, and I have tried to make it a point, that we feel that that is a very valuable program and should go ahead.

The contention is whether that development should be flown on a satellite, tested and demonstrated in orbit. There, there is a difference of opinion among the industry, not only, as you might suspect, between the satellite manufacturers, those that would be part of the program and those that would not, which is sort of obvious, but among the Earth station manufacturers, common carriers, system operators, and users.

As I understand it, you are going to have other hearings and other witnesses and get statements on this from others. It is my purpose, and I hope I have clarified the NASA position on why we have made the decision that we have. I personally support that decision and I think that it is, overall, a well balanced program and what we are doing within this particular ACTS program is very worthwhile, essential, and should go forward.

Mr. BATEMAN. Mr. Chairman, if I may have just a moment more. Not knowing a fraction of what I need to know about the Hughes announcement and application, what is it that they plan to do or wish to do? Does it include something that would be the equivalent of a demonstration and flight testing of the advance technology that you want to go forward with and ground test?

Dr. EDELSON. Hughes has filed with the Federal Communications Commission an application to construct and put into orbit a two-satellite system to operate at 30–20 GHz, which is the same frequency which we had selected for ACTS. Other than the choice of the same frequency band, the technologies are quite different. Essentially the ACTS technology is as yet undeveloped and 5 to 10 years in advance of what is proposed in the Hughes filing.

Now, let me add this other point: the Hughes filing is for an operational commercial system, and our proposal is for an experi-

mental system. So, they are quite different in intent and nature as well as in the level of technology.

Mr. BATEMAN. So, in your rethinking of it, I surmise that where you are coming from is that NASA should continue the ground-based research on advancement of the technology, but in view of the filing and an indication that industry is willing to do that which is within present state of the art and to actually demonstrate that state of the art, that it puts more on a back burner the degree of activity that NASA presently needs to undertake.

Dr. EDELSON. That is correct, absolutely correct.

Mr. BATEMAN. It is, indeed, an interesting area, Mr. Chairman, and I have learned something of it. I suspect I will need to do a bit more study before I have any conclusions to draw from.

Mr. LUJAN. Mr. Chairman, if the gentleman would yield, I would like to follow up a little more on that.

Then, if NASA is looking at a better communications satellite than what Hughes is—Hughes is limited, I understand, to just certain places—and the NASA one encompasses, let's say, the whole country, why then would funding be reduced for ACTS to get this better technology? Aren't you going to continue with it?

Dr. EDELSON. We are, Mr. Lujan, proposing and will carry out the technology development. The crying need is for the United States to develop this new technology and test it. We will do that, testing on the ground. The only question is whether the flight test in orbit is necessary.

Mr. LUJAN. You can accomplish the same objective you believe, maybe, by just the ground test?

Dr. EDELSON. I hope I haven't said that, Mr. Lujan. It is not the same, but we can accomplish some of the very valuable objectives by ground testing, and we wish to go ahead with that.

Mr. LUJAN. But, eventually, you will have to put up the advanced communications satellite?

Dr. EDELSON. Maybe not. Maybe industry will fly her.

Mr. LUJAN. That is what Hughes has been trying to accomplish, then, to move ahead of you.

Dr. EDELSON. No, I believe that it is fair to say that Hughes is trying to meet a market requirement, and they have laid out a system that they believe is optimized for the market they are trying to serve which serves 16 market areas. Our program is experimental and, in fact, admittedly, wouldn't make sense as an operational system. It is not a cost effective operational system. We are developing many technologies which would be used at other frequencies and would be very flexible. It wouldn't be limited, for example, to any 16 market areas. It could cover the whole country easily.

What we think we are doing by the ground test program, I should have said, is we are taking a major step forward in reducing the risk that industry would have to move into the next generation of communication satellites by having available, developed by the U.S. Government, this advanced technology. Again, the question is, Is it worthwhile and marginally cost effective—incrementally cost effective, I should say—to provide the flight test? We feel, and the administration has taken that position, no, it is not necessary and

it is not the best use of the funds within our program to do the flight test.

Mr. LUJAN. You don't think it puts us in the back seat of this technology vis-a-vis other countries?

Dr. EDELSON. We feel that we would definitely be in the back seat relative to other countries if we didn't develop this technology.

Mr. LUJAN. No, but doing just the ground testing? Do you think it is sufficient to keep us in the forefront, to keep us right up there?

Dr. EDELSON. I think we will—that is a hard question to answer. I would have to wait and see what happens, but if the technology—if we develop the technology, it is not used or employed by U.S. industrial firms, then I think that would turn out to have been not the proper decision. However, indications that we have, and Hughes' filing is evidence of that, that industry will step forward and will fly the technology that has been developed on the ground.

Mr. LUJAN. Thank you, Mr. Chairman.

Mr. VOLKMER. Rather than continue on with this, I would, Dr. Edelson, request that you do furnish us, in writing at a later date whenever you can, the differences between the ACTS program and the Hughes satellite. As I understand it, it is not only in the switching and the processing but also in the use of the actual waveband and how you use it, too.

Dr. EDELSON. That is correct.

Mr. VOLKMER. I would like to have those differences and then, along with that, how you plan to ground test those. I can see where some can answer questions about the others.

Dr. EDELSON. Yes, we will do that, Mr. Chairman.

[The information follows:]

COMPARISON OF PREVIOUSLY PROPOSED ACTS FLIGHT TEST PROGRAM VERSUS HUGHES FILING

IN ORDER TO FACILITATE A COMPARISON, THE FOLLOWING IS A LISITNG OF THE TECHNOLOGY IMPLICATIONS OF THE PROPOSED HUGHES SYSTEMS TECHNOLOGIES RELATED TO THOSE IN THE PREVIOUSLY PROPOSED ACTS FLIGHT TEST PROGRAM.

ITEM	PREVIOUSLY PROPOSED ACT FLIGHT TEST PROGRAM	HUGHES FILING
ACCESS	TDMA	FDMA/TDM
TRAFFIC ACCOMMODATION	DYNAMIC	FILING INDICATES FIXED; HUGHES NOW SAYS WILL BE DYNAMIC
COVERAGE	APPROX. 1/3 CONUS AT ANY GIVEN TIME	16 MAJOR CITIES
EFFECTIVE FREQUENCY REUSE	GREATER THAN 6	LESS THAN 3
ORBIT SPACING	1 DEGREE	FILING INDICATES 2 DEGREES; HUGHES NOW STATES 1 DEGREE CAN ALSO BE USED
ADAPTIVE RAIN FADE COMPENSATION	YES	NO

ANTENNA TECHNOLOGY

ITEM	PREVIOUSLY PROPOSED ACTS FLIGHT TEST PROGRAM	HUGHES FILING
TYPE	DUAL OFFSET FED	DUAL OFFSET FED
BEAM FORMING NETWORK	RECONFIGURABLE	FIXED
FIXED BEAMS	3	16
SCANNING BEAMS	2 FOR CONUS COVERAGE	0
ISOLATION		
SPATIAL	YES	YES
POLARIZATION	YES	NO
TIME	YES	NO

BASEBAND SWITCHING AND PROCESSING

ITEM	PREVIOUSLY PROPOSED ACTS FLIGHT TEST PROGRAM	HUGHES FILING
UPLINK AND DOWNLINK BUFFERING	YES	FILING INDICATES "NO"; HUGHES NOW SAYS WILL HAVE CAPABILITY TO ACCOMMODATE SPACECRAFT MOTION.
DEMODULATORS		
TYPE	BURST (TDMA)	CONTINUOUS (FDMA)
RATE (MBPS)	27.5 AND 110	1.5
NUMBERS REQ.	100's	1,000's
BASEBAND PROCESSING	ALLOWS SWITCHING OF INDIVIDUAL MESSAGES TO A SPECIFIC RECEIVING LOCATION	ALLOWS SWITCHING, BUT ALLOWS NO BASEBAND PROCESSING
BASEBAND CIRCUIT RATES	MULTIPLES OF 64 KBPS FOR ANY VOICE, VIDEO OR DATA SERVICE	1.544 MBPS
ADAPTIVE RAIN FADE COMPENSATION	FEC AND BURST RATE REDUCTION	NONE INDICATED IN FILING; HUGHES STATES HAVE FEC ON DOWNLINK (CONTINUOUS)

MATRIX SWITCH TECHNOLOGY

ITEM	PREVIOUSLY PROPOSED ACTS FLIGHT TEST PROGRAM	HUGHES FILINGS
RECONFIGURABILITY	DYNAMIC-- TRAFFIC REQUIREMENTS	DYNAMIC-- WITHIN 16 BEAMS
MATRIX SIZE	----------COMPARABLE----------	
SWITCH SPEED	20 NANOSECONDS	UNKNOWN (NOT STATED IN FILING)
SWITCH TECHNOLOGY	GaAs FET	UNKNOWN (HUGHES RECENTLY STATED VLSI WILL BE USED)

We are planning a restructured ACTS ground test program that will develop a communications system test bed which includes ground terminals, a master control station and a communications package based upon the proven proof-of-concept approaches and will further refine this hardware. The Communications package as currently envisioned would include a multiple scanning and fixed spot beam antenna, low noise receivers, a baseband processor, an IF switch matrix and a traveling wave tube amplifier. The test bed will also include equipment for simulating satellite motion, propagation effects and user messages. Extensive system testing will be performed to verify system performance, including bit error rate and an ability to overcome propagation losses.

Mr. VOLKMER. I would like to get on to other parts of the budget. I have so many questions relative to it, I don't know where to start.

I guess one of the areas I could start with——

Dr. EDELSON. I would like you to start with the easy ones. [Laughter.]

Mr. VOLKMER. Well, I don't know which one is really easy. Let's take the materials processing which is now the microgravity part of the budget. As I understand where we are going, we are probably getting into more program areas, but I see a reduction in the total effort, $600,000, and I would like to know the reasoning behind that.

I see research and analysis with a $700,000 increase over last year, but a reduction of $1.3 million in experiment operations.

Dr. EDELSON. Yes, Mr. Chairman, I am just finding my place in the book here. The number that we are asking for this year is $11.3 million. Last year—and that is above the amount we asked for last year. We have an expanding program. We are doing a great deal of——

Mr. VOLKMER. It is probably more than you asked for. It is not more than you got.

Dr. EDELSON. I am sorry. I was reading the wrong—that is the point I wish to make, but I read the wrong numbers. The 1984 authorization and appropriation, operating plan, is $23.6 million and this year, it is slightly under that, $23 million. The point I would make is that that is more money than we asked for last year. Congress saw fit to add some additional money to it, and——

Mr. VOLKMER. You are not deferring any of that money and you are not reprograming any of that money, are you?

Dr. EDELSON. No, indeed, we are not reprograming any.

Mr. VOLKMER. Well, my question is, how are we going to do more with less?

[Pause.]

Mr. VOLKMER. If you would rather submit that in writing, but I would——

Dr. EDELSON. I will give you a detailed answer in writing.

Mr. VOLKMER. I would like to have it.

[The information follows:]

During the past year, OSSA has taken steps to reorganize and strengthen the management and role of the microgravity discipline to take full advantage of an operational Space Shuttle; therefore, we believe we will have a stronger program in FY 1985 even though the proposed funding level does not increase. For example, we are setting up microgravity center(s) of excellence to allow the microgravity community to have more input into our planned activities. In addition, we have placed a great deal of emphasis on identifying how more flight opportunities could be made available to the microgravity community and, consequently, we are agressively pursuing the development of instruments which can be flown on the Shuttle orbiter mid-deck. In addition to reassessing the Research and Analysis portion of the Pro-

gram, emphasis is being placed on the construction of small, relatively low-cost instruments for flight. As more data becomes available, and is analyzed, we anticipate a more aggressive program in future years that will continue to be responsive to the research community.

Dr. EDELSON. The points that I would make is that this is $1.4 million more than we asked for last year. Last year, Congress added the $2 million and was specific with instructions which we are carrying out. We are currently, at the present time, reassessing our program. We have a new expanded effort in this area. Mr. Richard Halpern, the distinguished bearded gentleman over here, has taken hold of that program and is building it up. We feel that this is a good and adequate amount of money to do the program as we now envision it.

Mr. VOLKMER. Basically, what I read into it is that you are basically sticking along with your guidelines as to what you had last year and, in spite of our giving you more, you are going to go back to basically where you were the year before the 1985 budget cycle. Is that correct?

Dr. EDELSON. No, we are stepping up the budget with our request and have put in there all that we could make available in our request. It is always a question of priorities in different areas, and we feel that we have an adequate program here which we are now reassessing and adjusting as much as we can.

Mr. VOLKMER. All right. This brings me to the point within that budget about our centers of excellence that the Congress started in this committee and the Congress appropriated funds for, provided authorization for last year. In the first place, I have another question in regard to that before we get into the funding part.

In your statement, you referred to a university center on bioprocessing research. In our report in the language that we used, we requested a center for basic research in the separation and purification of organics. Why the difference?

Dr. EDELSON. Let me ask Richard Halpern, the director of Microgravity Science and Applications, to address that question, Mr. Chairman.

Mr. VOLKMER. Yes, I would like to have that.

Mr. HALPERN. Mr. Chairman, there really is no difference. It is a matter of terminology, and the intent is to, as I testified before this subcommittee last year, to continue to follow the mandate that this subcommittee laid down. Bioprocessing, if you will, is a shortcut term to do just exactly what you intended to do.

Mr. BATEMAN. Mr. Chairman, would you yield for a moment on that point?

Mr. VOLKMER. All right. Go ahead, if you have a question on that point.

Mr. BATEMAN. If the two terms are synonymous, why not add to the understanding of the committee by using the terminology that was used here rather than changing it to something else that means the same thing?

Mr. HALPERN. We certainly will take that under distinct advisement.

Mr. VOLKMER. Just as long as we understand we are talking about the same thing.

Mr. HALPERN. We are, sir.

Mr. VOLKMER. And the requirements that go out in an RFP are not being changed as a result of the terminology? As I understand it, we are about ready on the RFP?

Mr. HALPERN. We have been working with the Space Applications Board, the Pharmaceutical Manufacturers Association, and the USRA, put together a committee to help provide criteria for that notice—I call it a notice, Mr. Chairman, rather than an RFP, and that is a procurement legalism—and we are discussing right now with a very distinguished researcher who has had experience in industry, in the Government, and in academia, to become chairman of that committee, and I hope to have his acceptance within the next few days. Assuming that this gentleman accepts, I would hope within a month to have that out on the street.

Mr. VOLKMER. What out on the street?

Mr. HALPERN. A notice to universities that NASA is interested in establishing centers of excellence with criteria upon which to have those universities propose.

Mr. VOLKMER. In other words, the notice will go out sometime perhaps in March, then?

Mr. HALPERN. I am hoping to do that, yes;

Mr. VOLKMER. At least by April 1?

Mr. HALPERN. That is correct.

Mr. VOLKMER. Will it be sufficiently detailed so that any university that wishes to apply will have sufficient criteria in it so that they know whether or not they would have an opportunity or it would be worthwhile to apply? In other words, that they would meet some of the criteria that are going to be designated? Is that correct?

Mr. HALPERN. That is correct, sir.

Mr. VOLKMER. And, what is the timetable after that? Let's say, how long a time do they have to respond?

Mr. HALPERN. We have not established that, Mr. Chairman, but it may be of interest to you and the other members of the committee that following my testimony last year, I have received——

Mr. VOLKMER. How many?

Mr. HALPERN. At last count, it was 18, Mr. Chairman.

Mr. VOLKMER. I am sure of that because I have had some talk to me.

Mr. HALPERN. The reasoning for mentioning that is that one of the things that I have discussed with the universities, as they have indicated their intent to propose, is what they feel a reasonable time would be. Most of them indicate between 45 and 60 days, and we will take that under advisement when we put out this notice.

Mr. VOLKMER. That puts us up to sometime probably in May.

Mr. HALPERN. Yes, sir.

Mr. VOLKMER. Then we are going to have to have a time to review all of those that come in.

Mr. HALPERN. Yes, sir.

Mr. VOLKMER. And pick out 1, 2, or 3, or whatever is decided. So, probably summertime or sometime before any announcements are made then, would it not?

Mr. HALPERN. I would hope, Mr. Chairman, that we could do that early in the summer.

Mr. VOLKMER. I would hope so too, because otherwise, what I am looking at is that the funding that we put in for the 1984 budget cycle, we are only going to have a quarter left for any funds to go out, so I think we ought to look at what happened to the rest of the funds and what is going to happen there.

Now, what do we have next year for the centers of excellence and for bioprocessing?

Mr. HALPERN. I believe that there is sufficient moneys in 1985, Mr. Chairman, to take care of continuation of the centers of excellence. You have not, of course, established the number yet.

Mr. VOLKMER. I know, but I would like for you to let us know again in writing, before not too long, how much you anticipate using out of this budget item here for the centers or center, whatever it is.

Mr. HALPERN. Yes, sir. We will do that.

[The information follows:]

Although the exact number of Centers, and their specific funding levels, has not been established at this time, we expect to be able to select from one to three Universities in FY 1984. Assuming a grant level of about $400K for each Center, we will award $400K-$1,200K in this Fiscal Year. These awards are typically committed for three years at the same levels. Therefore, we would expect to spend between $400K and $1,200K again in FY 1985.

Mr. VOLKMER. I appreciate that. All right. That takes care of my—all right. That basically, I would say, will take care of that area.

I would like to get now into the question of what I call research analysis throughout the budget, and I find in the physics and astronomy a slight increase. I find in planetary exploration—let's see, what is this?—a decrease. Those are the sciences basically pertaining to the planetary science, while I find an increase in communications research analysis which I relate more to a commercial end, and I would just like to know again the reasoning behind those, especially the reduction in the planetary, research analysis in planetary, this year $59.5, and then in 1985 it's $54.5.

Dr. EDELSON. Let me tick off some numbers here, Mr. Chairman, in answer to your question.

The overall research and analysis budget is up from $312.5 to $325.9, and so overall we are up 4 percent in research and analysis.

Mr. VOLKMER. Yes, but where is it put? That's what I'm saying.

Dr. EDELSON. Yes. The area in which you are looking at research and analysis, planetary, is one that caused us a lot of consideration, and we worked hard to squeeze everything in there that we could. Planetary, as you may notice, is up a great deal itself—32 percent. We had a new start last year and we're asking for a new start this year.

The sum total of research and analysis and a related line item, mission operations and data analysis, goes from $103 million up to $113 million, so the total of the two—MO&DA and R&A—is up some 10 percent. The other positive thing I can say about research and analysis in planetary is that over the last few years it has gone up, and it is up some 17 percent over the 1982 figure.

We are engaged, as you know, in this area to try to fulfill the recommendations of the SSEC. We're aiming at a $300 million a year planetary effort altogether. We're aiming at getting the re-

search and analysis level up to the 1981 level, and we have not yet done that but we are moving in that direction; and we are aiming at getting both the planetary observer category and the Mariner Mark II category started.

The story that I'm telling you is that we have—we believe we're making great strides in planetary exploration but we have not been able to get enough money in all areas, and that particular area of planetary R&A is not up to where we would like to see it, but that is a balance of all of our objectives and we feel that we are doing a good job and the best we can in fulfilling the recommendations of the SSEC.

Mr. VOLKMER. Are we basically going back to what we did under the materials processing or microgravity, in our analysis budget, and saying that the $59.5 was above what you proposed and you've gone back in 1985 basically? In other words, the $54.5 is probably more than your budget request last year.

Dr. EDELSON. Yes, that's correct. It is.

Mr. VOLKMER. If we put additional money in there, authorized, and it's appropriated, would you use it for that purpose.

Dr. EDELSON. We would, Mr. Chairman, but as I would like to say right along—and which is certainly our position—and that is, we had many concomitant goals and a number of conflicting desiderata when we put this budget together, and we're trying hard in all these areas. We feel that overall we've got an adequate and very well balanced budget.

In answer to your specific question, could we use more money if we had it in this area, the answer is yes, we could.

Mr. VOLKMER. On the physics and astronomy and the mission operations and data analysis, the increase there, is that on the new center for the telescope, most of it, at Johns Hopkins for the Science Institute?

Dr. EDELSON. Yes. The Science Institute is funded under the operations line item, under MO and DA——

Mr. VOLKMER. Right. I just wondered how much of that increase——

Dr. EDELSON [continuing]. Space telescope operations.

Mr. VOLKMER. That's under physics and astronomy, isn't it, and you've got a figure here of 1984 of $68.1, 1985 of $109.1, which is a $41 million increase, a good increase, and I figure that most of that increase is because of the Science Institute but I would like to know how much of it, what the breakdown is.

Dr. EDELSON. We can't track the numbers exactly. The numbers that we're looking at here for the space telescope operations are, 1984, $34 million, and 1985, $49 million, an increase of $15 million. Most of that is for the development of the so-called SOGS, the space telescope science operating ground system, and we are very deep into the development of the software for that system, and that $15 million increase is mostly in that area.

Mr. VOLKMER. All right. Before I get into it, I want to know that you're well aware of Dr. Donahue and Dr. McDonald's report and the universities' and NASA and Space Science's. More funding is needed for university research equipment. How much do we have in this budget, because I can't find it with these figures. How much is going to university equipment?

Dr. EDELSON. We took the recommendations of the Donahue and McDonald committee very seriously and we considered them. We did not establish a separate line item for university equipment, although we considered it. We do have a great deal of funding in the R&A line item which is a pretty significant total, $326 million. Of that, university funding in total goes from $156 million up to $178 million, which is a 13-percent increase, and significant part of that $178 million going to universities will go into equipment and instrumentation, but rather than single it out and say to any particular grantee, "You have to use so much for instrumentation alone," we have tried to fund it all in that area.

Mr. VOLKMER. What about graduate fellowships?

Dr. EDELSON. We do not have any specific line item for graduate fellowships, Mr. Chairman.

Mr. VOLKMER. I know, but do we have a program? Are we going to provide any funds?

Dr. EDELSON. Let me get Dr. Rosendhal to——

Mr. VOLKMER. If you don't know for sure, I'd like to know in writing.

Dr. EDELSON. I'll provide that information for the record, Mr. Chairman.

Mr. VOLKMER. And if not, why not; if so, how much?

Dr. EDELSON. All right, sir.

[The information follows:]

The Agency coordinates an overall funding plan for graduate student researchers. The OSSA contribution to that plan will be about $2M in FY 1985.

Mr. VOLKMER. And I would like to know, like on the instrumentation, even though you may not be able to give us an exact figure I think you can give us a fairly rounded figure as to this total of $178, how much would be for equipment or instrumentation.

Dr. EDELSON. We'll do that, Mr. Chairman.

[The information follows:]

Our preliminary assessment of the total funding which will go to educational institutions in FY 1985 from Space Science and Applications is on the order of $175–180 million; our best assessment of the amount which will be used specifically for instrumentation is on the order of approximately $20 million.

Mr. VOLKMER. I've taken up more than my time. I will have additional questions I want to give to you in writing, but I've got some more members here that came in and they may have questions, too, and then we still have another witness to go.

I now recognize the gentleman from Pennsylvania, Mr. Walker.

Mr. WALKER. Thank you, Mr. Chairman.

Let me ask you, if I could, about the international aspects of the program. How would you characterize NASA's current role and influence in foreign policy decisions as they relate to space applications, space science?

Dr. EDELSON. That's——

Mr. WALKER. Well, is it adequate?

Dr. EDELSON. Yes, I can answer that question. Our general policy is that we are promoting international cooperation in space science, very much, and we are doing that because science itself is international, because there is good capability in other countries, and because we help share the costs. In applications we are consid-

erably more constrained, and we have a concern about technology transfer there, so we have a very positive policy in science and a somewhat restricted policy in applications.

Mr. WALKER. Is it your impression, in having worked with foreign governments and in that particular arena, that they are cooperative or that they are difficult to work with

Dr. EDELSON. I would say extremely cooperative.

Mr. WALKER. Is it your impression that they are eager to engage in more such projects with us, or that they are somewhat restrained in their willingness to participate?

Dr. EDELSON. They are eager to engage in more cooperative projects with us, Mr. Walker.

Mr. WALKER. So in other words, insofar as NASA can reach out to the international community, we are very likely to find them receptive to our initiatives, and the restraints are primarily ours with regard to applications, as you have put it, in the technology transfer area.

Dr. EDELSON. That's correct.

Mr. WALKER. Thank you, Mr. Chairman. That's all the questions I have.

Mr. VOLKMER. I now recognize the gentleman from Florida, Mr. MacKay.

Mr. MACKAY. I would like to just ask you in general how the recommendations of the committees that have studied the space science program, how they have been incorporated in. Do you agree with the recommendations? One of those had to do with the stability of program, and although you seem to have incorporated part of it, the minimum core idea doesn't seem to be incorporated in there. That was your Solar System Exploration Committee. Do you agree with their recommendations?

Dr. EDELSON. Yes; we do agree with their recommendations. The Solar System Exploration Committee itself was very effective. We had an opportunity to work with that committee, which had very broad membership, over a period of more than 2 years—3 years—under a succession of very effective chairmen. We had representation on the committee, as did other advisory committees.

It was—the results were useful and effective, and we're trying to carry them out to the very best of our ability, and that's largely due to the fact that they were composed of very technically competent people and that they inserted a great deal of discipline in their work and organized it well and, as is obvious, they presented it well. They presented it in a brochure form, in presentation form, in scientific article form, in such a way that it gave NASA a very excellent road map of how to proceed, and the program which I'm presenting today is in large measure a direct outcome of the SSEC recommendations.

Mr. MACKAY. The specific item that was left out—or seems to have been left out, I'm not sure—is the planetary observer.

Dr. EDELSON. The SSEC, Mr. MacKay, recommended two classes of spacecraft, planetary observers and Mariner Mark II, somewhat larger, more extensive. The Mars orbiter that we are proposing as a new start in the fiscal 1985 program is the first of the planetary observer class. We are requesting, in this budget, approval of this

first satellite itself rather than the class of spacecraft, so we are using the terminology of the first mission rather than of the class.

Mr. VOLKMER. Will the gentleman yield on that? Will the gentleman yield on that just a moment?

Is there a possibility in the future to insure, or at least have a little more insurance of an ongoing program, that we could see a line item such as planetary observer program, and underneath that you could have the various satellite denominations that are ongoing.

Dr. EDELSON. We would like that very much, and we believe that it would be a very efficient and effective way to perform. That is essentially what we have done in the Explorer class of satellites, and it gives us the opportunity for multiple buys. For example, the one that's second priority to the Mars orbiter is a lunar orbiter. We would design the spacecraft and instrumentation and supporting systems to fit both of those, and we would have multiple procurement.

As it is, with approval of the first class, we feel, however, that this will give us a way to get started. We will be able to prove to the scientific community, to the OMB, and to the Congress, that this is an effective program, and that sooner or later we will be able to develop that into an ongoing class with budget stability, as we have earned the right to do, I believe, in the Explorer class.

Mr. VOLKMER. All right. That I agree with, but now I want to ask you another question, if the gentleman would yield further in that regard. How long do I look? In other words, if I'm looking at the 1986–1987–1988–1989–1990 budget, how long before we find our second planetary observer class and satellite?

Dr. EDELSON. We would expect that if the Mars orbiter is approved in the 1985 budget, that we would consider requesting the lunar orbiter in the 1987 budget at the earliest. Now we've got a lot of hurdles to go through before then, but it would be desirable to have one of these every 2 years or so, as recommended by the SSEC.

Mr. VOLKMER. Uh-huh.

I yield back to the gentleman from Florida.

Mr. MACKAY. I don't mean to be quibbling, but it seemed to me the major point that they were making was that there would be a great deal to be gained from a commitment to a stabilized program, that you were committed to the program not to one at a time, and I can see where other institutions that are trying to interrelate with you would benefit from that commitment. It seems to me that to the extent they made that point, your response was unresponsive to their recommendation. We were curious as to whether that meant you're committed only to one, that it's a tentative commitment, or whether you disagreed with what they were saying.

Dr. EDELSON. You're correct, Mr. MacKay, that was their recommendation and their purpose was to obtain stability in the program, and further to encourage NASA to be self-policing within the program, so that if we had a budget level—let's say we're spending $50 or $60 million a year—that would be self-policing, and we would do as much as we can within the $50 or $60 million a year. We wouldn't try to——

Mr. MACKAY. Put another priority ahead of it.

Dr. EDELSON. We wouldn't put another priority ahead of it, and we would devote it all to the lower cost, similar missions and try to use a maximum amount of redundancy in systems and so on, so that it would be cost effective. However, we didn't have the temerity to ask for approval of the whole class without any demonstrated proof on our part, on NASA's part, that we could in fact pursue that. I believe that we will be back in a future year and ask for approval of planetary observers as a class.

Mr. MACKAY. In the meantime, we have no way of being assured that you have a sufficient level of commitment so that you will go forward with it.

Mr. EDELSON. Well, I think it's fairly obvious to our advantage to do a very good, cost-effective job on this first mission, to keep the pressure on our institutions—in this case, JPL—and our contractors to perform in this area as we have performed in the explorer area and to gain this. It's a goal all around. We just felt like not going for—going whole hog on the first submission and introduction of this new class.

Mr. MACKAY. All right. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you.

The other gentleman from Florida, Mr. Nelson? Any questions?

Mr. NELSON. No, Mr. Chairman.

Mr. VOLKMER. I will have some more questions to be submitted in writing. I appreciate your taking the time with us. I know it has been about 2 hours, and I'm sorry I was a little late to get started today, but it's just one of those things—too busy a day, too many things going on—so I appreciate your being here and look forward to the rest of the questions, answers to the questions we will be submitting in writing and those that have been deferred from the day.

Dr. EDELSON. Thank you, Mr. Chairman. We'll try to be very responsive to your questions.

Mr. VOLKMER. Thank you very much, Dr. Edelson.

Our next witness will be Dr. Thomas M. Donahue, Chairman of the Space Science Board, National Academy of Science.

Dr. Donahue, your statement, which I have examined—and appreciate your furnishing it in advance—will be made a part of the record in total at this time, and you may either review the statement or summarize, however you desire. You may proceed, Dr. Donahue.

STATEMENT OF DR. THOMAS M. DONAHUE, CHAIRMAN, SPACE SCIENCE BOARD, NATIONAL ACADEMY OF SCIENCES

Dr. DONAHUE. Thank you. Thank you, Mr. Chairman, for giving me the opportunity to appear here today to comment on scientific issues in the space program and NASA's fiscal year 1985 budget request. If you feel that it would facilitate the proceedings today, I can simply assume that this statement is in the record and proceed with questions, or go through it if you desire.

Mr. VOLKMER. If you wish to review some areas, we've got time.

Dr. DONAHUE. Well, then, let me proceed.

Mr. VOLKMER. I've got another hour, and your statement isn't that long, so if you've got the time, I've got the time.

Dr. DONAHUE. Good. Well, I have a plane at 5:10.

As I am sure you know, the Space Science Board is charged by the National Research Council with responsibility for watching over the health of space science. That responsibility is reflected in the strategies for research developed by its various committees to guide NASA in the assessment of the responsiveness to those strategies, of the science content of the NASA missions, of the quality and long-range planning, and also very important, the substance and adequacy of the supporting elements of the U.S. space programs at universities, centers, and institutes.

Of course, the overriding issue in fiscal year 1985 is the request for a start on the space station and the impact that initiative will have on space science. The Subcommittee on Science, Technology, and Space of the Senate held hearings on this matter last fall, and I had the privilege of testifying at that time. I refer to that testimony, a copy of which is attached to my statement, and shall not repeat it in detail in my oral presentation.

If the Congress agrees with the administration and authorizes it to proceed with the construction of this facility, the board will cooperate in every way in its power to maximize the usefulness of the space station to science. We have expressed this determination to Mr. Beggs, and I am pleased with the level of mutual understanding that seems to exist between us on this issue but, of course, as I also said in my testimony to the Senate, we are concerned lest the bad experience space science has had in coexisting with the space shuttle development program be repeated with the space station.

There exists a large number of excellent space science missions already developed in concept and responsive to the strategies of the board and its committees that do not need the space station for their implementation. If the Nation wishes to continue to be in the forefront of science in space, then means will have to be found to launch science missions at a reasonable rate with existing spacecraft while the space station is being prepared. If further delays in starting and orbiting high-priority missions while we wait for the space station should be added to those already imposed while we waited for the shuttle and its upper stages, space science will be left in a state of extreme atrophy.

I hope that a cap will not be placed on the NASA budget during the years ahead that has the effect of preventing space science from expanding to the level of increased activity implied by the establishment of the space station, and I hope that means will be found to build a wall, a fence around the space station project so as to protect other important NASA programs.

As I also said in my earlier testimony, care must be taken as the space station is being defined and after it is in place to accommodate science missions that do not lend themselves readily to close support by the space station because of the orbit needed or other requirements. We are pleased with the willingness expressed by NASA to make usefulness to science a major factor in designing the space station. The formation of a space station task force of the Space and Earth Sciences Advisory Committee is a positive step. I understand that you will be hearing from Dr. Banks, the chairman of that task force, tomorrow. So, also, would be a decision to ask the Goddard Space Flight Center and the jet propulsion laboratory,

as representatives of the space science component of NASA, to play an integral, high-level role in planning the space station. It would also seem to be wise for NASA to establish some administrative apparatus at headquarters, perhaps under the chief scientist, to represent science at a high level and guard against a deterioration of the science mission of NASA of the sort that occurred during the decade of shuttle development.

Turning now to the specifics of the fiscal year 1985 requests in space science, I am pleased to see three proposed new starts. In some respects this is an encouraging budget for space science. It has been a long while since three new starts were requested.

We have waited a long time to see the upper atmosphere research satellite—UARS—get underway. It is indeed time that we prepare to obtain a global inventory of trace gases in the upper atmosphere simultaneously with measurements of wind and temperature. These are needed to understand the impact of life processes on the surface and in the waters of the earth on the upper atmosphere.

Flying a scatterometer on the NOSS mission will provide us with some of the data we need to understand the global circulation of the ocean. I hope that NASA follows through promptly in the coming years to complete the job by coming forward with proposals to start TOPEX, the ocean topography experiment, and GRM, the geodynamics research mission.

The appearance of the request for the Mars geoscience climatology orbiter is a welcome gauge of NASA's responsiveness to the solar system exploration report. Unfortunately, I have to note with regret that the administration has failed to respond to a key element in the recommendations of the SSEC—that this mission be the first in a level-of-effort series called the planetary observers.

These observers are not just a planetary entitlement program. Stability and affordability was what the SSEC was trying to bring to the base program in planetary studies. In doing so, it was being responsive from Members of Congress and from the science advisor. Commitment to level-of-effort funding is necessary to provide stability, flexibility, and economy in this new way of doing business in planetary exploration.

In astronomy and astrophysics I fear that we are seeing the effects of the space telescope overruns on other programs. The proposed funding for the advanced X-ray astronomy facility experiments is welcome but probably not adequate. There is no money requested to start work in defining the space infrared telescope facility, and the solar optical telescope is still delayed.

All that I can learn indicates that the serious technical problems with the space telescope are behind us, as we heard just now. There seem to be no show stoppers ahead. The fine guidance system works, the mirror can be cleaned, the latches have been fixed, and it still looks as though the instrument will emerge from Perkin Elmer on time. If no serious problems develop during integration at Lockheed, the telescope should be ready for launch at the revised date. Obviously, however, there is no guarantee that some delays won't occur, but NASA management seems quite firm about meeting the schedule and holding to the present budget.

NASA must guard, however, against allowing this preoccupation with management problems to cause it to forget that the purpose of the mission, after all, is to do science. It is most important that the Space Telescope Science Institute be fully ready to support the operation of the facility once it is operating. I have great confidence in the competence and dedication of the institute staff to do so if NASA provides them with the means in a timely fashion. When this great and costly instrument becomes ready to operate, we must be in a position to exploit its capabilities from the very beginning.

We also suggest that plans be developed for a program of preventive maintenance of the telescope after it becomes operational, and that way we will be able to prevent problems from developing that might take months or years to fix because of a lack of such a program. Furthermore, the practical experience gained in servicing the instrument periodically ought to prove very useful in case an emergency should develop.

The Hubble space telescope and the science institute will profoundly change the future course of American astronomy in a way not fully perceived by the astronomical community. With the establishment of a permanent observatory in space, space astronomy will achieve a level of maturity that will require more effective coordination between the space-based and ground-based organizations. It follows that there may be a need for an advisory structure that can communicate to all agencies concerned with astronomy. The definition of this structure will require careful study by the various agencies, by the National Research Council, and by the Congress.

Last year when I appeared here I commented on the sensitivity NASA was showing toward the problem of the poor health of university space science research groups. As a token of that sensitivity, a committee on NASA-university relations was formed, chaired jointly by the chief scientist of NASA, Dr. Frank McDonald, and myself, and consisting of representatives of the university community, including the Space Science Board, and NASA. This committee recommended several emergency measures to NASA management in order to provide immediate succor to these university groups. Two of these recommendations have been adopted, it is my understanding. They are for the establishment of NASA graduate student traineeships, and enhancement of data analysis at universities for science missions now existing or already finished.

A third recommendation was for an $11 million annual commitment for laboratory equipment needed to end the state of obsolescence of that equipment in many university research laboratories. This state has developed over the years because of the erosion that has taken place in supporting research and technology—now research and analysis, or R&A funding. A serious state has been allowed to develop in our university laboratories. Unfortunately, the budget request does not contain a line of funds needed to respond to the third recommendation.

Erosion of research and analysis funding would have been much more serious than it has been if the Congress had not intervened to increase funding when the administration has come forward with inadequate requests. Again this year the R&A requests fall short of

the levels established by Congress last year. This is perplexing in view of the increased level of science activities implied by the new starts. Such an increase needs an enhancement of R&A support, and not a decrease.

The increases requested for shuttle payload development, for the suborbital program, and for explorers are laudable, especially if they reflect a preoccupation with increasing the rate at which flight opportunities will become available for small, university-sized payloads. A question, however, is whether the plans for using these funds provides for carrying through on the experience with spacelab 1. It's very important that we exploit our experience with the space shuttle to develop an adequate mix of shuttle payloads from large facilities to small PI class experiments.

One area of space research that traditionally has been one of the strongest in the space program is that of solar and space plasma physics, including solar-terrestrial research. During the past few years this field has suffered from a series of management reorganizations at NASA that left the disciplines less than adequately represented. Their science programs seem to have suffered accordingly.

This year there are several welcome harbingers of change. One is the UARS—upper atmosphere research satellite—initiative. Another is the appointment of a vigorous and effective discipline chief. The third is the energetic promotion and planning for an international solar terrestrial program involving the United States, Europe, and Japan by the Office of Space Science and Applications. This program would include elements of the origin of plasmas in the Earth's neighborhood—the OPEN mission for which we have been waiting so long.

On the other hand, I do not believe that this budget contains a continuation of funding for payload development for this program. I note an effective decrease in R&A requested here also. The concern of the Space Science Board for this discipline is expressed in the charge we have given to our Committee on Solar and Space Physics to conduct a programmatic priority study of the sort already carried out by the Astronomy Survey Committee—the field committee in astronomy—and the Solar System Exploration Committee. We shall be pleased to share the findings of that study with you when it has been completed, and would welcome any suggestions from you or your staff on questions that it might or that it ought to consider.

Last July a workshop was convened by the National Research Council under the leadership of Dr. Herbert Friedman to review the major problems for research in the atmosphere, oceans, lithosphere, biosphere, and solar-terrestrial relations. The participants in the workshop concluded that an international geosphere-biosphere program—IGBP—could provide an effective means to coordinate global measurements from space platforms and ground-based networks of the entire geosphere-biosphere system. The theme of that program would be to understand global change on time scales covering a range from a few decades to hundreds of millions of years.

The workshop called for national organizations in other countries to come to the International Council of Scientific Union general assembly in September 1984 with preliminary plans to imple-

ment this program. The NASA global habitability program fits well into this larger international program as part of our national participatory effort, one focused on characterizing global change on the relatively short time scale of a few decades. Of course, UARS represents a major component in the NASA program and that is one reason that we are so pleased to see it in this year's budget request.

You have asked that I comment on the study of the mission of NASA carried out by the NASA Advisory Council, of which I am a member. The parts of this study pertaining to space science have some interesting and stimulating suggestions. In fundamental science there is a concern expressed for the stability of funding, a concern we share and one that found expression in the work of the NASA-University Relations Committee that I have already discussed.

As for their recommendation that NASA take the lead role in assuring the activities sponsored by NASA and the National Science Foundation are properly coordinated, I concur that coordination is necessary. I am not sure, just not sure of the rationale for NASA taking the lead role, given the charter of the National Science Foundation to take care for the health of all of the science in the United States.

In solar system exploration we heartily concur in recommendations for a more aggressive pursuit of the technologies of robotics, teleoperation, and machine intelligence, and for the institution of measures to insure steady funding levels and program continuity. The study recommended also that a major goal of planetary exploration should be understanding the solar system for ultimate human benefit.

I would agree with the Solar System Exploration Committee, rather than with the Advisory Council, that this should be a goal but a secondary one. The primary goal should remain the determination of the nature of the planets, comets, and asteroids in order to understand the origin and evolution of the solar system and how the appearance of life is related to the chemical history of the solar system.

In summary, then, let me repeat how pleased I am to find three important initiatives in space science in the budget request, and emphasize the hope that we shall proceed with care if we go forward with plans to establish a space station—care for the health of the space science programs.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Donahue follows:]

Prepared Statement of Thomas M. Donahue, Chairman, Space Science Board, National Academy of Science

Thank you Mr. Chairman for your invitation to testify on the space station issue. My name is Thomas M. Donahue; I am on the faculty of the University of Michigan and am the chairman of the Space Science Board of the National Academy of Sciences. It is the ongoing task of the Board to provide independent advice and guidance to the conduct and substance of the U.S. civil space science program and the major technical initiatives to implement such programs.

The Space Science Board recently produced two brief reports dealing with space science issues raised by NASA's proposal to establish a space station in a low inclination orbit by the end of this century. I have attached these reports to this statement along with the transmittal letter that I sent with them to Mr. Beggs, the administrator of NASA. So here I shall only very briefly summarize the content of these reports. The first report addresses the question of whether the space station now proposed would significantly enhance the usefulness of space science missions it proposes to support above the level they would achieve if the present space transportation system alone were available to launch and support them. In view of the fact that the mission set in question was designed around expendable launch vehicles, the shuttle and appropriate upper stages now being developed it is hardly surprising that the answer turned out to be negative. It is important to note that the Board addressed the question of how much we need this particular space station 48 percent of whose projected activity is stated to be support of a particular set of space science missions. We explicitly remarked that we could envision other kinds of space stations, designed to

do other things such as providing an assembly base for construction of large structures or new kinds of space craft on orbit that might be very useful to space science missions of the future. We suggested that we might be able to get enthusiastic about such a space station. However, it is only fair to say that I doubt that these kinds of activities alone could ever come close to justifying entirely the establishment of such a space station. Indeed, we also pointed out in our second report our conviction that in defining the properties of a space station one should have very clearly in mind all of the major functions it is supposed to perform. To be explicit, if -- sooner or later -- the space station is supposed to provide a base for expeditions to Mars or to the Moon then that activity will so overwhelm the support of the platforms and free flyers of space science and applications that one should pay attention from the beginning to the requirements of the more ambitious application of the space station. I am not saying that the proposed space station will not serve well as a step toward that ultimate space station. I only point out that we have not seen the evidence that the issue is being addressed or that we understand the tradeoffs.

You might ask why we insist on evaluating the space station in terms of our present set of missions and do not consider revising them radically in view of the possibility that novel ways of configuring and servicing missions from a space station might be developed and provide us with exciting new capabilities. The answer is partly that we are not being challenged to do that with the present proposal. It is also

partly that our plate is very full with the present set of missions. We are very excited about their potential to provide us with fundamental insights into how the universe began, insights into grand unified theories of physics, into questions about how the planets and the sun developed and life began, into how life on earth impacts and is impacted by changes in the atmosphere, the oceans and the solid planet. We consider this to be a very worthy agenda; we consider the technical means now becoming available adequate to allow us to get on with it, and, especially after our experience with long frustrating delays waiting for that system to be put in place, we are very resisting to risking another wait for another promised enhancement in supporting technology that, in our opinion, offers no apparent qualitative advantage over the shuttle system for science. That technology ought to grow in response to experience and evolving requirements and not to be artificially introduced in such a way as to drive its uses.

In fact it is significant that the pressure to build a space station is not coming from potential users such as space science and applications. Those who are pressing for a space station are making a laudable effort to involve those users in defining the characteristics of the space station so that it will be useful to them. This is in contrast with what happened when these communities were presented with the space shuttle and space-lab, two previous systems imposed on them. But, nevertheless, I have to emphasize the importance of the observation that technical means should develop in response to user needs and not the other way around.

It is often said that our response to the proposed space station is a consequence of our fears that science budgets will suffer from competition with Office of Space Flight budgets if the nation should embark on a new and ambitious space station program. This is not an accurate characterization of our position. A very simple examination of the record will reveal that the budget for space science has remained fairly close to a fixed fraction of the total NASA budget through all of the 25 year history of the space program. During the years of the Apollo era this fraction served to support a vigorous and productive science program. During the years of the shuttle it has not. The reason is that during the sixties and early seventies the science budget was being used to build space craft, to launch them, and to finance the science groups that used them. During much of the last ten years approved space science missions have been waiting on the ground to be launched because of delays in getting the shuttle operational and the unavailability of expendable launch vehicles. Thus the budget has been used to support the infrastructure of engineers and technicians that must be maintained to take care of these missions until they are launched and not to prepare and fly new missions. The rate of launching space science missions has dropped from 5 or 6 per year in the late sixties to about one per year now. Thus we have warned that, if the nation wishes to continue to do space science while a space station is being developed, the means to launch and support space science missions and to support the space science community will need to be preserved concurrently. Nevertheless,

the budgetary impact may occur; we are watching with great interest to see what is in the agency's FY 1985 budget request. If the budget implication of large sums for the space station and for the consequences of management defects in developing the space telescope are failure to propose new starts for the Upper Atmosphere Research Satellite, for the Mars Geoscience Climatology Orbiter, the first planetary mission in the Planetary Observer series recommended by the Solar System Exploration Committee, or the various measures needed to bring emergency aid to failing university space science research groups the conclusion will be obvious. Early this year, after the magnitude of the problem with the space telescope development was revealed, we expressed to NASA and to the Congress our hope that the penalty for management failures would not be assessed against science. It is already clear, however, that the Advanced X-Ray Astronomy Facility and the Solar Optical Telescope are being delayed. Personally, I am apprehensive that delays also will be imposed on some or all of these other science missions that I have mentioned. If this turns out to be the case and at the same time funds are requested for a major new initiative for other elements of the space program, then a strong statement will have been made concerning priorities. If this is, indeed, the direction in which the nation desires to take its space program, that is its perogative. The duty of the Space Science Board is to make sure that the scientific consequences of such a decision are spelled out.

Let me return to the statements the Board has published on the Space Station for a moment. We recognize that space science

and applications are not the only ends of the space program -- not by any means. We have not taken a position for or against the space station, although many read our position to be negative. We hold that the decision to build a space station will be made for reasons other than its usefulness to space science and applications alone. In this regard, we are not far from the position taken by Vic Reis this morning. We also recognize that a healthy space agency is necessary for a healthy space science program, and that permission to embark on an ambitious new program such as the space station may be necessary -- or at least very salubrious -- for the health of NASA. With these factors in mind we were reluctant to produce the judgement we did on the need of space science for this space station. However, the reason the Academies have established advisory bodies such as the Space Science Board and the Space Applications Board is to provide clearly independent advice on scientific and technical issues to those in government who must come to decisions on those issues. A crucial question is whether science can get along without the proposed space station, and how well it can get along. These questions are very different from the question of whether we could use the Space Station if it were to be built, or could use some kind of space station which may not even be the one proposed. Earth Sciences, for example, need observatories in high inclination, sometimes sun-synchronous, orbits. Such platforms and free flyers could benefit from services rendered by a manned space station in a high inclination orbit. But they could also be serviced from a space shuttle sortie in such a high inclination orbit. Thus to say that these observatories would be benefited merely because they are part of an overall plan, labelled a space station plan, that does not provide for the matching manned space station element would be an empty endorsement. It is one that we chose not to make.

I hope that these remarks, coupled with the documents I have submitted will clarify some of the issues you must confront or provoke questions that I shall be pleased to try to answer.

NATIONAL RESEARCH COUNCIL
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND RESOURCES
2101 Constitution Avenue Washington, D.C. 20418

SPACE SCIENCE BOARD

OFFICE LOCATION
JOSEPH HENRY BUILDING
21ST STREET AND
PENNSYLVANIA AVENUE, N.W.

September 9, 1983

Mr. James Beggs
Administrator
National Aeronautics and Space
Administration
Washington, D.C. 20546

Dear Jim:

Last September the Space Science Board agreed to work with NASA in determining the technical capabilities a space station should have in order to address effectively the scientific objectives of the various space science disciplines. During the past year, the Board and its committees have had frequent interactions with the NASA Space Station Task Force, led by John Hodge, in fulfilling that commitment. We have been very favorably impressed by the careful consultation with the community of potential space station users that NASA has maintained during this exercise. In due time, we plan to transmit to you formally the results of the past year exercises by the Board and its committees.

Mr. Hodge has briefed the Board concerning the characteristics of the space station now being proposed by NASA. In the reports enclosed with this letter, the Board addresses two separate issues. The first issue is the degree to which the space station now being considered will be required in order to reach the objectives of the Space Science disciplines during the next twenty years. This evaluation, in the Board's opinion, must be made in the light of the adequacy of the presently available space transportation system to meet space science needs without augmentation by the proposed space station capabilities. Our finding is that present systems are adequate to these needs. Therefore, on the issue of meeting the needs of space science, our recommendation would be to use the space shuttle, together with requisite upper stages, maneuvering and propulsion systems for missions to be flown during this century. To meet longer range science objectives, a space station might prove to be very useful in various ways if it were suitably designed. The Board would be happy to work with you to define such a space station if you proceed with plans for it.

As we pointed out in our letter of September 13, 1982, the Board agrees with you that the question of whether to go forward with a space station is not apt to be made on the grounds of its usefulness to space

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations

science and applications alone. Thus, the report entitled "Space Science Board Assessment of the Scientific Value of a Space Station" should not be regarded as establishing a Board position on the question of whether the nation should or should not now or in the future develop such a space station. On the other hand, the Board has considered some additional issues that lie within its competence. These have to do with conditions that should exist as any space station is being developed and after it becomes operational, if a healthy and vigorous space science program is to be maintained concurrently. A discussion of these issues is the content of our second report, "Space Science in a Space Station Era" which is also being forwarded to you with this letter.

Sincerely,

Thomas M. Donahue
Chairman

cc: F. Press
P. Smith
H. Friedman

SPACE SCIENCE BOARD ASSESSMENT OF THE SCIENTIFIC VALUE OF A SPACE STATION

During the past year, tne Space Science Board has examined the question of what space systems are required to launch and support adequately the space science missions designed to attain the high priority science objectives identified by the Board and its committees. These missions are very numerous, challenging, and exciting. However, the rate at which they are launched would have to increase significantly above the current rate if all of the missions needed to fulfill this program are to be flown during the next two decades. The means of launching and tending them is now available or being developed in the form of expendable launch vehicles and the space shuttle, augmented as required by adequate high energy upper stages. One reason for the present slow pace is the delay in bringing the shuttle and its upper stages to full operational status. Another is that we have not yet learned how to use the shuttle efficiently and effectively as a manned orbiting laboratory. The Space Science Board urges that the present launcn systems be fully and flexibly exploited and adequate resources be brought to bear so that the stated objectives of space science can be reached in a timely fashion. The results of following this course should be a rich harvest of discoveries and insights in all disciplines of space science.

The Space Science Board has carefully examined the proposal by NASA for a manned space station in low Earth orbit designed to engage in a number of major activities. A significant portion of these activities involves support of space science missions. The Board has also examined the set of specific missions proposed for implementation from the space station system during the years 1991-2000. It has found that few of these missions would acquire significant scientific or technical enhancement by virtue of being implemented from this space station. In view of this and the adequacy of the present space transportation system for the purposes of space science, the Board sees no scientific need for this space station during the next twenty years.

In the longer term, the Space Science Board sees the possibility that a suitably designed space station could serve as a very useful facility in support of future space science activities. Such a space station could provide means for erecting and fabricating large and novel structures in space, and for servicing, fueling, and retrieval of payloads in orbit. If NASA wishes to develop plans for such an ambitious and technically demanding space station for the next century, the Space Science Board would be pleased to work with NASA in defining the properties of such a space station.

SPACE SCIENCE IN A SPACE STATION ERA

In a recent statement entitled, "Space Science Board Assessment of the Scientific Value of a Space Station," the Space Science Board has addressed the issue of the space science need for a space station. It found no need for a space station to support missions addressing high priority science issues for the next two decades. On the other hand, it found that a suitable space station could offer important services to space science in the more distant future.

The Space Science Board realizes that the nation may decide to commit itself to the deployment of a space station in support of needs and objectives other than or in addition to those of space science alone. The characteristics of such a space station should be carefully determined to conform to the principal activity that it is intended to support. For example, it is not obvious that a space station optimized as a transportation node for travel between the Earth and other solar system objects would also be an entirely suitable platform from which to launch and support science and applications missions. Whatever the eventual properties of such a space station, there will probably be a set of high priority science missions that require orbits and operational support for maximum effectiveness other than those available from that station. If a space station program should be undertaken and it is meant to be useful to space science, the Space Science Board urges that the means to initiate and operate space science missions in a timely fashion and in reasonable accord with priority ordering of those missions be maintained. Ordering of missions would then be determined by scientific priority rather than the nature of the launch or support system required. The Board also urges that the scientific program be structured so as to be protected from delay in space station development or changes in its capability.

The Board also wishes to make the following specific recommendations and observations.

Scientific instruments that can be deployed in orbits compatible with space station orbits should be flown in optimal scientific orbits and on separate platforms if that is necessary to preserve them from contamination, interference, and degradation of pointing stability and control that may be associated with the manned modules.

If the space station is designed to provide a servicing capability beyond that provided by the shuttle, that capability should allow retrieval of instruments from a wide variety of orbits.

The deployment of a space station designed in part to support space science implies an increase in the level of space science activity above that presently planned. If such a space station is to be utilized effectively, the space station system should be accessible and affordable for scientific use, and there should be a real increase in the level of support for that activity.

A commitment by the nation to long duration human space flight, whether in Earth orbit or beyond, calls for the establishment of a facility for space biological and medical research on the effects on individuals of very long exposure to the "low g" environment. In this sense, the relationship of the life sciences to a space station is a special one.

Thus, a manned space station could eventually provide significant opportunities for a number of disciplines in space science provided there is a commensurate increase in the total level of space science activity. Realization of those opportunities would depend on the extent to which the capability to carry out space science research is kept viable, important experimental and theoretical activity is continued, and new endeavors are initiated while the space station is being developed. After the space station becomes operational, realization of those opportunities would depend on the provision of a sufficient number and variety of flight opportunities, many involving unmanned space craft and flight to regions of space near the Earth and further out in the solar system at distances and locations inaccessible to a manned platform.

Mr. VOLKMER. Thank you very much, Dr. Donahue.

Before we proceed with questioning, I just want to find out, does your plane leave from National or Dulles?

Dr. DONAHUE. National. I'm fine.

Mr. VOLKMER. OK. That gives us a little more time.

I would just like to go on a couple of things, and then we will go to other members of the committee. Now, you mentioned here in your statement, and I noticed it when I was reading it, that with the establishment of a permanent observatory in space, space astronomy will achieve a level of maturity that will require more effective coordination between the space-based and ground-based organizations.

Could not the National Research Council—doesn't it have members that are both space- and ground-based, and could not out of that come such a coordinating body?

Dr. DONAHUE. Oh, indeed it could.

Mr. VOLKMER. You are on the Space Science Board. I'm sure there is a group that are ground-based, and surely they could work together.

Dr. DONAHUE. Yes; I think it is an activity that simply must, that the National Research Council must get around to undertaking. We are beginning discussions within the Space Science Board itself and also with Dr. Friedman and Dr. Press about how best to go about providing this advice.

It may be that, given the increasingly large amount of activity in astronomy that in the future that will be in space, that locating this advisory structure within the Space Science Board and its Committee on Space Astronomy and Astrophysics will make sense with some enlargement of the committee, or some other joint committee with, say, the Physics and Astronomy Board of the National Research Council is the way to go.

We also have to work out—I think we have to be sure that the agencies that we advise are receptive of that advice. It doesn't do any good to give advice if nobody is out there listening, and so I think we need a little bit more exploration with the agencies involved here—that is, with the National Science Foundation and with NASA—to make sure that they are receptive to this advice.

Mr. VOLKMER. All right. Getting back into an area which you discussed, in your study along with Dr. McDonald on university-NASA relationships, you comment on them, except for the question of instrumentation or equipment, whatever we were talking about. We don't know, but I think that they are going to be able to provide us with a dollar figure on how much of that—what they say is now $178 million—is for instrumentation. Assuming that there is $11 million in there, I would like to know if you feel that this budget reflected a positive response to those recommendations, assuming that that money is in there.

Dr. DONAHUE. All right. I will assume that, reluctantly, however.

Mr. VOLKMER. Right. Well, I'm not saying it is yet.

Dr. DONAHUE. I understand.

Mr. VOLKMER. But, I mean, assuming that, is there anything else, in other words? I know that but is there anything else that you——

Dr. DONAHUE. No; apart from that I am quite well satisfied because I do—I have an understanding, and perhaps I speak to a different part of NASA than Dr. Edelson has been speaking to, but I do understand that funds can be found to take care of the recommendation for the graduate student traineeships and also for at least some portion of the increase in funding for university-centered data analysis that we recommended.

But we recommended $20 million additional to that end, advised by discipline chiefs at NASA, and I think that provided the research and analysis funding is increased above the level of the request, provided that happens, that we can find in the MO&DA line the extra funds needed for the data analysis. If not, then I am afraid that MO&DA funding will be diverted to support research and analysis, effectively, and won't be available for the purpose that we recommended it, so I think it's very important that something be done to restore the R&A funding level to that which Congress visualized last year when it increased the request once before.

Mr. VOLKMER. Now we're talking about, on the R&A level, basically in the planetary exploration area.

Dr. DONAHUE. Well, there are hidden problems in other areas as well. It's conspicuous in planetary. We——

Mr. VOLKMER. Physics and astronomy?

Dr. DONAHUE. Well, I think what has to be realized about the physics and astronomy R&A request or R&A plans is that they do contain the funding for the instrumentation, the instruments on the advanced X-ray astronomy facility. I understand there is something like $3 million involved there for AXAF instruments; $6 million were requested by NASA for this purpose. This means that that R&A line, when you subtract out the amount that is going this year for the first time to AXAF instruments, represents the decrease—taking into account inflation—in the physics and astronomy R&A line as well. I defer to the experts from the space science working group who will, I think, appear here tomorrow, or soon.

Mr. VOLKMER. They are just submitting a statement.

Dr. DONAHUE. I see. OK, fine. It's not our business to make a detailed analysis of the shortfall but it's in the neighborhood of $5 to $10 million in physics and astronomy. It's simple arithmetic to ask what you have to add to the planetary R&A line to get back to the fiscal 1981 level, allowing for inflation, that we've all identified as the minimum viable level. That's $14 million.

Mr. VOLKMER. The gentleman from Virginia.

Mr. BATEMAN. I have no questions this afternoon, Mr. Chairman.

Mr. VOLKMER. The gentleman from Florida, Mr. MacKay.

Mr. MACKAY. I am not sure I clearly understand one paragraph on page 10 of your written statement and, if you would, I would like you to refer back to that.

Dr. DONAHUE. Yes, sir.

Mr. MACKAY. Are you saying that there is one place where the study by your group overlapped with the study of the Solar System Exploration Committee, and that you agreed with the recommendation of the Solar System Exploration Committee?

Dr. DONAHUE. Yes, sir. I should explain I was also a member of the Solar System Exploration Committee.

Mr. MACKAY. All right. I would like to follow through that. Now my understanding is that that committee said, "Look, get something basic and fundamental pinned down and follow a basic core and get that done. Set your priorities in that way." And that your committee took a more expanded view and didn't concentrate so much on that basic core idea. You are saying on page 10 that you agree with that, that the basic priorities should remain the determination of the nature of the planets, comets, and asteroids in order to understand the origin and evolution of the solar system and how the appearance of life is related to the chemical history of the solar system.

Now when you say it should remain that, does that imply that the Solar System Exploration Committee is saying, "Stay with what you're doing with your basic core," and that this other study recommends, in effect, "Let's start out on something more expensive, although we haven't done the first year." Am I reading too much——

Dr. DONAHUE. Yes, sir, I do agree that you're probably reading a little too much into what I said and into what the NASA Advisory Council said and what the SSEC said. It's a question of emphasis. The Solar System Exploration Committee did spend a great deal of time considering whether the goals of solar system exploration should be expanded to accommodate exploitation of the moon, of the asteroids as a possible source for resources on Earth, and concluded that that should be added as a goal but remain a subsidiary goal, secondary to that of the fundamental goal of understanding or trying to understand where the solar system came from in the first place; in other words, that the emphasis should remain on basic science and this other goal be secondary.

The only difference between it and the Advisory Council was that the Advisory Council recommended that this other goal be brought up to the same level, and I don't—I guess that one's concern is that perhaps the entire program might get torqued if the goal of going to asteroids to determine whether there are resources there that we can use here on Earth were to become a dominant one in the program. We just think "first things first." The first thing to do is understand the whole system and then later get on with the business of exploiting it.

Mr. MACKAY. Do you have any views—now that we have the experience of the space shuttle program having preempted the science effort for a period of time, you on two or three occasions talked about the need to "wall off" basic science from the space platform—do you have any specific ideas? Does that imply a structural reorganization of some kind or a budgetary differential, or how could we do this, other than——

Dr. DONAHUE. Well, I am really—I would be getting beyond my—I mean, going beyond my credentials as the Space Science Board chairman if I were to make specific recommendations about how NASA ought to do its, carry out its mission. But I am very concerned that overruns in the program as we go along—we have never had one of these programs that didn't overrun—that if there is a cap on the budget, that the overruns will threaten the space science program.

One might consider various techniques for preventing that by, say, making the space station program a level-of-effort program, and thereby prevent it from—prevent overruns from occurring and threatening the rest. Then we could indeed live with a cap that involved some modest measure of increase every year, as we have heard may well have been agreed on by NASA and OMB. A 1 percent real increase per year for the next 5 years would represent a healthy increase in the level of activity, if the space station doesn't need it all.

Mr. MACKAY. So the failure to make the space station a level-of-effort program carries a risk that if it overruns, it will impact others like perhaps the planetary observer, and the failure to make it a level-of-effort program magnifies that risk?

Dr. DONAHUE. That's right. That seems to be a reasonable analysis. I'll probably get my knuckles rapped for getting—going beyond my charter in this way, but I am worried about the health of space science and that's my primary concern. I am quite concerned about living along with this—in a stall with this big elephant that's going to be in there with us.

Mr. VOLKMER. But it's not necessarily a white elephant.

Dr. DONAHUE. Not necessarily. [Laughter.]

Mr. MACKAY. I thank you. That was eloquent.

Mr. VOLKMER. The gentleman from Florida, Mr. Nelson.

Mr. NELSON. Good afternoon. I want to ask you, your continuing concern that space science is not cut as a result of the space transportation system and now the space station, let me just ask you the basic, fundamental question about building a space station that is manned as opposed to one that is all automatic, nonmanned. How about giving me some of your feelings about that?

Dr. DONAHUE. Well, I have to confess that I am one of those who believes that we could achieve our objectives in space exploration by using robots and teleoperated machine intelligence in orbit, and make use of the life support systems that we already have available to us on Earth to accommodate man in the loop down here on Earth rather than in space. It is more or less an act of faith—it is to a certain extent an act of faith—but I have a personal conviction that this would be an exciting way to carry out our space objectives.

On the other hand I am, I think, realist enough to feel that we probably can't sell that way of doing, of achieving our objectives in space, and that the manned space program is with us and will continue to be with us. It also is an effective way of operating. We have already seen that for the past couple of decades.

I would submit that neither one of these programs, whether it is manned or unmanned, is a burdensome tax on the Nation or on the world. A $7 billion program for these objectives, whether it's a $7 billion program with man in the loop or a $3 or $4 billion program without man in space, is a bargain for the country and for the world in the measure of—measured in terms of the amount of knowledge that it is bringing to us in thrusting technology ahead to the cutting edge, and so it's a bargain either way and I don't have any problems living with a manned space program and a manned space station. It's another way of doing business and I think it can be made to work.

Mr. NELSON. Do you think there is some truth to the practicality of Washington politics, that "no Buck Rogers, no bucks?"

Dr. DONAHUE. Yeah. Uh-huh. [Laughter.]

Mr. NELSON. Let me explore. You know, we're sitting up here. We're going to have to help make policy about an $8 or $9 billion investment. Under the theory that you propounded, that you could probably do it all automatic instead of man in space, under that theory would—the logical extension of that theory is that we really didn't need a manned spacelab, that there are experiments that you could do and you don't have to have the man up there in orbit. Is that basically where that theory leads you?

Dr. DONAHUE. It would lead me there. We are a long way from having demonstrated that we can work in that mode. We have gone much further in the past couple of decades toward demonstrating that we can do it with man in space, and so I think it would be probably more dangerous than is warranted to suggest that we stop now with the manned space program and learn a new way of doing business.

Mr. NELSON. You often hear people say: "But man in the loop in space, the hands-on experience, the real-time experience of man, broadens the horizon, gives us a greater opportunity for development in space." Do you just basically disagree with that statement?

Dr. DONAHUE. I think that it's quite—I think that it's possible, it is possible that robotics could be developed and machine intelligence could be developed so that all of these pattern recognition and decisionmaking advantages that are claimed for man in space could be developed by another system. It is rather interesting that on the Earth we are going in the direction of converting our factories and laboratories to automated, robotic factories, whereas in this field which is supposed to—in which we are supposed to be developing the most advanced technology in the Nation, we're not, or should I say we're not going fully in that direction.

Mr. NELSON. What about the capability of some scientific experiments, if it were all automated. Do you think you could do all of the materials processing, all of the pharmaceutical manufacturing? Could that all be done automated, without man in the loop?

Dr. DONAHUE. Well, I could try to cop out by saying that this is applications and not space science, but I guess I won't, and say that I suspect yes, that you could do without the human intervention in running those furnaces in orbit.

Mr. NELSON. Can you think of any areas where judgment needs to be made by a human in the space environment that would lend itself to science?

Dr. DONAHUE. Well, in a way that could not be exercised by a human on the ground in a control center, provided there is enough development of the means to communicate with the device in space, I think it's not impossible that you could do without the presence of man to make those judgments in orbit.

Mr. NELSON. Why do you think the Soviets have been fooling around with having men in a spacelab kind of environment for the last decade or so?

Dr. DONAHUE. Well, they probably—they may well have the same—some of their—some people in the Soviet Union may have the same problem selling a space program without man in space

that we have over here. I doubt that they have any greater wisdom that we don't have, as that they know some secret about the effectiveness of man in space that we're not aware of.

Mr. NELSON. If we had sent a probe to the Moon and back instead of it being a manned Apollo program, would we have developed all of the technology spinoffs that we now enjoy in our everyday lives? Would that technology spinoff still be there?

Dr. DONAHUE. Well, that's another—you know, President Roosevelt used to call that kind of question a "what if" or an "iffy" question, but I don't see why not. It seems to me that developing the kind of technology that you would have to develop to have robots running around on the surface of the Moon and collecting samples and loading them on a vehicle and shipping them back to Earth and collecting them here on Earth, that kind of technology would push us at least as much as the technology that we had to use to get man to the Moon, walking around with backpacks and space suits and riding dune buggies over the surface of the Moon. It might well have been that the technology spinoff would have been greater. I suspect that it would have.

Mr. NELSON. I would like to follow this up, Mr. Chairman, and ask some questions in written form, and I appreciate the opportunity.

Thank you very much, Dr. Donahue.

Mr. VOLKMER. I know that there probably will be continuing discussion from the time on as to whether we need a manned or unmanned space station, but I would like to get into one area: On spacelab 1, would you consider that, as far as science is concerned, a successful mission?

Dr. DONAHUE. I think it's a little early to judge. I would rather reserve judgment until I see the scientific returns. I myself am a coinvestigator on one of the experiments that was flown on spacelab 1, the Utah State experiment on the imaging spectroscopic observatory, and we don't have our data yet; I haven't seen the data and hence it's a little early for me to be throwing my cap in the air.

Mr. VOLKMER. All right. In the question of the space station, and I know you're concerned about the budgetary overruns and things and what happened with the shuttle in relation to science, but on another area in relation to science objectives and with the space station, do you see or do you have any concerns about the possibility that in the future—if the space station, assuming that it is done and in 1992 we have it there—that science experiments, it will be said to NASA, "You're going to run them through the space station." Do you have that concern?

Dr. DONAHUE. Well, we do have that concern. We expressed that concern in one of the position papers that we developed last summer and sent to the Administrator, and that position paper or report is attached to the testimony that I submitted today. Yes, there is—we have a number of concerns.

One of them is that there will be a tendency to mount on the platform, either the manned capsule or the platform that accompanies the manned space station, as many observatories, as many instruments as can possibly be accommodated there, even though that platform may not be in the orbit that is optimal for the exper-

iment, even though there may be problems with heat-loading, vibration, contamination, and so forth. Just the tendency will be to bring everything on board, and it has to be guarded against. There also will be the tendency to favor those missions that can be accommodated in this mode over others that have perhaps higher scientific priority but need a different orbit.

All of those things are concerns of ours, and I think I can illustrate the nature of this concern by pointing to an existing NASA mission that is in danger of being torqued in this way, and that is the space infrared telescope facility. I call it the space infrared telescope facility. I think it may still be called the shuttle infrared telescope facility.

As you know, it was—this facility was—it was originally designed to be flown on the shuttle in the sortie mode. I think that was a mistake from the beginning, that this should have been a free-flyer from the start. It is true that until IRAS succeeded, well, in the unclassified domain there was not confidence that one could maintain cryogens in orbit for periods of as long as a year, but once that is demonstrated then that facility, that observatory ought to be a free-flyer. It should not be flown on the shuttle, and that has been recongized and NASA is in the process of transforming SIRTF from a shuttle facility to a free-flyer.

But in doing so, that violates one of the givens of the Field Committee report, which was that SIRTF would exist as a shuttle facility. Once it becomes a free-flyer, it is redefined and it gets into a priority contest with other observatories and other facilities such as AXAF, and that means it probably has to be delayed and fly later than it otherwise would as a shuttle facility. We may not see it come as a new start until several years after AXAF, but that gets it so close to the space station that there is a large temptation to grab it again, reconvert it from a free-flyer, put it on the platform, and it becomes then one of the primary candidates for a platform facility and we won't be seeing it until 1997 or something of that sort.

So this, I think, illustrates—I can see that in action right now where SIRTF is concerned. It is, it seems to me, a good example of the way the tendency to push things onto the shuttle or push things onto the platform that ought to be free-flyers does influence the overall program.

Mr. VOLKMER. Is that because of additional costs that SIRTF occurs as being a free-flyer rather than on the shuttle, or——

Dr. DONAHUE. No; I think it doesn't.

Mr. VOLKMER. What is the——

Dr. DONAHUE. I'm not sure that it actually involves much more in the way of cost to fly SIRTF as a free-flyer. I'm not sure about that, but there is——

Mr. VOLKMER. A priority——

Dr. DONAHUE [continuing]. It does have to be—I beg your pardon?

Mr. VOLKMER. What is the reasoning, then, to say that a delay will take place by it no longer being on the shuttle but becoming a free-flyer?

Dr. DONAHUE. Well, there are—the mission does have to be studied as a free-flyer. It involves, instead of just putting——

Mr. VOLKMER. Controls?

Dr. DONAHUE. No; it's a question, mainly a question of the coolants, of the cryogens. It makes a big difference whether you have to have liquid helium for a year in space on a free-flyer or replenished periodically by the shuttle, or carry the thing in the shuttle bay and bring it back after a week, so technically it's a different mission than the shuttle, than SIRTF on the shuttle, and——

Mr. VOLKMER. But is there that much difference if it is going to, as a free-flyer, if it is going to be in basically the same orbit that it would as on the shuttle? Wouldn't you be able to just take the arm and place it out and bring it back in?

Dr. DONAHUE. Well, it's not clear that it would be in exactly the same orbit, but it of course needs its own power supply in orbit.

Mr. VOLKMER. But the infrared showed us 10 months.

Dr. DONAHUE. Yes, yes. This is a bigger, much bigger facility, though, than an IRAS. I'm sure it's feasible. It's just that one has to go back to the drawing board and restudy it.

Mr. VOLKMER. I see.

I don't believe I have any further questions. Does the gentleman from California have any questions?

Mr. LOWERY. Mr. Chairman, yes, to follow up on the specific you asked regarding the spacelab and space telescope.

Dr. Donahue, what would you say are the relative tradeoffs between a shuttle, a manned space station, and a free-flyer? Are there various experiments that are oriented more toward one than the other?

Mr. DONAHUE. Yes, there are a lot of missions, Earth-oriented missions, for example, that require high inclination orbits, polar orbits. At the present time there is no plan to have a—well, the initial space station will be in a low-inclination orbit, about 28.5 degrees. Until and unless a space station in high-inclination orbit, a manned space station, becomes available, then the polar orbiting free-flyers obviously are on their own.

But many, many satellites require special orbits, such as sun-synchronous orbits which are not the shuttle orbits, and another difference between free-flyers and instruments on the space station involves a need for precise pointing toward stars, for example, in the case of observatories, where the motion of people moving around in the space station would disturb the pointing and degrade the performance in that way.

The dumping of wastes generally—the shuttle is a rather dirty bird. It has got a lot of effluents around it that tend to interfere with the transmission of ultraviolet radiation, if you want to observe with an ultraviolet telescope, and so instruments of that sort you don't want to have tacked onto, certainly don't want to have tacked onto either the shuttle or to a manned space station where vibration and contamination would interfere with them.

Mr. LOWERY. Following up on my colleague from Florida's questions, it seems that there are some experiments which are more appropriate with man in the loop in terms of correcting some of the defects. I think on the spacelab, there were a number of experiments that we were able to save because of manned involvement to make corrections, if you will. How important is that?

Dr. DONAHUE. Well, I think, you know, it's important to avoid those mistakes. The manned space program—the science program has been launching satellites and space probes that have established a remarkable record for reliability and longevity: Pioneer 10, going out of the solar system, launched way back in the midseventies and still going strong; Voyager 2, now approaching Uranus. Although Voyager 2 has had problems, problems with the scan platform that it developed while it was traversing the rings of Saturn, but the people at JPL managed to work those problems from the ground, talking to the spacecraft up there, and they have those problems under control.

So you can make fixes of that sort in two ways, either with somebody riding along with Voyager or with somebody sitting on the ground and being clever down here.

Mr. LOWERY. Do you think that same application could be made to other types of experiments where corrections could be made electronically, for instance?

Dr. DONAHUE. I don't see why not. I don't see why not.

Mr. LOWERY. How about costs?

Dr. DONAHUE. I think it would be less expensive to do it without the cost of building the life support systems to accommodate people, but——

Mr. LOWERY. Is there not more flexibility with man in space?

Dr. DONAHUE. Maybe, and maybe not. It's a subject that, in the case of man in space, we pretty well know what we can do. I repeat that it's a system that has been working and I am not—I responded to the question from the Congressman from Florida, Mr. Nelson, in the spirit of spirited discussion—but I wouldn't like to go away from here on the record as advocating abandoning the manned space program and going to an unmanned. That I'm not doing. I think it would, you know, it would be a mistake to throw away all of the experience that we have gained in the interest of fixing something that is not broken. The manned space program works, and why fix it?

Mr. LOWERY. Thank you.

Thank you, Mr. Chairman.

Mr. VOLKMER. The gentleman from Florida.

Mr. MACKAY. Just one more question: It seems to me that in a positive way, you are sounding some warnings, based on your experience, that this subcommittee would be well advised to heed. In the second page of your testimony, you said—you really made two warnings, as I understand it: one, that if there are cost overruns in the space station, we have got to guard against what happened with the shuttle, which is that the science programs got put back in order to utilize funding that could have potentially have been theirs to bring on the shuttle program; and, two, that—and I want to make sure this is what you said—that after it's in orbit, its being there might cause a redefinition of further science efforts so that those which could utilize it and thus provide a further justification for why it was we did that might be favored over those which are equally or more important but don't utilize it and would be seen as competitors. Is that what you said?

Dr. DONAHUE. Well put. Yes, sir.

Mr. MACKAY. I think that's a major problem that ought to be considered, although I don't know how you can do it except to be aware of it from the outset. The establishing of a level of effort and the establishing of a set of programs at the outset would be one good way to guard against that, it would seem to me, so we could remind ourselves what our priorities used to be.

Dr. DONAHUE. Yes, sir. I agree.

Mr. MACKAY. Thank you.

Mr. VOLKMER. Thank you very much.

Thank you very much, Dr. Donahue, for being with us today, and you have a safe trip back to California.

The subcommittee will stand adjourned until tomorrow morning at 9:30.

[Whereupon, at 4 p.m., the subcommittee recessed, to reconvene at 9:30 a.m., on Wednesday, February 8, 1984, in room 2325, Rayburn House Office Building.]

1985 NASA AUTHORIZATION

WEDNESDAY, FEBRUARY 8, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:40 a.m., in room 2325, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Present: Representatives Volkmer, Nelson, Dymally, MacKay, Winn, Lujan, Walker, and Chandler.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

Today we continue our hearings on NASA's space science and applications programs, with special emphasis on applications. We will also hear from the American Institute of Aeronautics and Astronautics, who will of course testify more broadly about the entire NASA program.

An issue that is raised in the AIAA statement is the lack of a long-range plan for NASA. Certainly we have been pushing NASA to formulate such a plan for years, however, without success.

Our first witness will be Mr. George Harter, Chairman of the Space Applications Board, National Research Council. He will be followed by Dr. Elizabeth Young, president of the Public Service Satellite Consortium, and Dr. Alan Lovelace, vice president for public policy, American Institute for Aeronautics and Astronautics. I welcome all of you here this morning.

Mr. Harter, your statement will be made a part of the record and you may either summarize or you may read it in total, however you so desire.

Before we start, I would like to recognize that we have with us today the ranking minority member on the committee, Mr. Larry Winn of Kansas, and I welcome him here today.

Mr. WINN. Thank you, Mr. Chairman.

Mr. VOLKMER. We also have the ranking member of the subcommittee, Mr. Lujan, and I will recognize him at this time for an opening statement if he so desires.

Mr. LUJAN. Mr. Chairman, I don't have an opening statement. I just note that yesterday we had interesting discussion on space science programs, particularly as to the mission of NASA, remote sensing and the space station, materials processing, things of that nature, and of course I am interested in hearing from today's witnesses on those and other subjects.

Thank you very much, Mr. Chairman.

Mr. VOLKMER. Thank you.
Mr. Harter, you may proceed.

STATEMENT OF GEORGE HARTER, CHAIRMAN, SPACE APPLICATIONS BOARD, NATIONAL RESEARCH COUNCIL

Mr. HARTER. Mr. Chairman and members of the committee, on behalf of the Space Applications Board of the National Research Council I would like to thank you for the invitation to participate in this hearing. My purpose is to present, as you had requested, the current thinking of the Board on the NASA space applications program.

As you indicated, my name is George Harter. I have been a member of the Space Applications Board since 1981 and have been chairman since December 1982. I am presently employed by TRW, Inc. in Los Angeles as vice president and assistant general manager for the electronics and defense sector. Since joining TRW in 1957, I have held a number of technical and managerial positions with the company in the spacecraft and electronic fields, and a brief biography is attached to this statement for your use.

The Space Applications Board was formed by the National Academy of Engineering in 1973, and is now part of the National Research Council, which is the operating organization of the National Academies of Sciences and Engineering. The Board's functions are to help formulate the Nation's program for practical application of space systems, to give independent advice to NASA and other agencies, and to assist in broadening the understanding of industry, universities, Government, and the public of practical applications of space technology.

Mr. Chairman, your letter of January 4, 1984, asks that we address three subjects: first, NASA's space communications research program; second, NASA's program of materials processing in space; and, third, the place of the applications program in the mission of NASA. I will speak at some length about the first subject and will review briefly our views on the second and third, and in addition I will have some comments on the proposed space station and its practical applications.

The Space Applications Board has been a proponent of the advanced communications technology satellite program since its inception. In 1975 NASA asked the Board and the Board agreed to study the question: Should Federal research and development on satellite communications be resumed and, if so, what is the Federal role in this field?

A committee on satellite communications was formed under the SAB and was chaired by Wilbur B. Davenport of the Massachusetts Institute of Technology. The committee's report entitled "Federal Research and Development for Satellite Communications" recommended that NASA implement an experimental satellite communications technology flight program in concert with the communications industry.

NASA responded by planning and initiating an advanced communications technology satellite that incorporates many pioneering technologies—the use of 20 and 30 gigahertz frequency bands; multiple-scanning, spot-beam antennas with onboard switching; time-

division multiple access; and baseband processing in the satellite. These advanced techniques open the way toward a greatly expanded U.S. telecommunications capability in the decade of the 1990's. It would be a tragic mistake, it appears to us, to lose this opportunity and to yield U.S. leadership in satellite communications to other nations.

It is part of NASA's role to insure that there will be sufficient capacity so that the country's space communications needs can be served. The only way to accomplish this goal is to develop improved technology. In the past several years, some of the country's best university scientists and communications and aerospace engineers have worked with NASA to delineate a program that will provide for conservation of the electromagnetic spectrum by means of novel and improved processing and transmission techniques.

This program was previously referred to as the 30/20 gigahertz program. However, the emphasis should be less on the frequencies—although it is important to open them up to commercial exploitation—but more on the technology that is being developed. At this stage the program appears ready to enter an intensive period of test and development that will culminate in flight testing of the relevant technology. We hope that these facts will be considered as NASA sets its future priorities in this area.

We believe that the evidence of this country's need for continued growth of space communications capacity is clear. We also believe that NASA is the appropriate agency to sponsor high-risk research and development activities that will result in improved services to users through the strengthening of U.S. industry. We hope that NASA will move toward early implementation of the ACTS flight program.

With respect to materials processing in space, a committee of our Board, under the chairmanship of William Slichter of Bell Laboratories, issued a report in 1978 that prescribed a program of ground-based research and development, supplemented by occasional flight testing of promising processes. NASA, in following this program, has established cooperative research activities with some 30 to 40 universities and research agencies and has developed a commendable background of research in materials sciences and technology. In addition, NASA has begun to use the shuttle as a vehicle for pilot testing of materials processing in space. We believe that this program is proceeding well and is properly funded. As I will point out later, materials processing may be one of the more important uses of a future space station.

With regard to the recent "Mission of NASA" study, I was personally invited to be a member of the study task force by virtue of my chairmanship of the Space Applications Board. The task force recommended that NASA should have a strong and productive program in space applications, oriented principally toward and development of new technology, but including flight demonstrations and early operational support for selected programs which were both in the national interest and could not be totally financed by an aggregation of private users.

In recent months our Board has been studying the field of remote sensing in space, which in our opinion is in serious trouble.

NASA's activities in remote sensing, including R&D, where NASA used to be a leader, have been dangerously curtailed.

Our Board's standing Committee on Practical Applications of Remote Sensing from Space is attempting to develop a future strategy for this field. The committee is made up primarily of users and processors of remote sensing data. Their views as to the near-term and long-term needs for and the uses of such data will be the central element of the strategy we intend to develop. The committee has planned a workshop for July of this year and anticipates issuing a report by late 1984.

In the meantime, our Board, with the assistance of this committee, is examining present and past institutional arrangements, both public and private, in the remote sensing field in an attempt to answer one basic question: Who should do what in the future? This is indeed a difficult question. It does not make sense, in our preliminary viewpoint, to dump the entire responsibility into the lap of industry and say, sink or swim.

As a minimum, it appears to be in the public interest for NASA to have a long-term role as a developer of new technology for remote sensing. Whether or not our Board will recommend that this role should include flight demonstration and operational trials remains to be determined. Our Board hopes to be in a better position to comment on these matters by late spring or early summer, and we will be pleased to share our viewpoints with you at that time.

As I mentioned earlier, Mr. Chairman, I would like to conclude with some remarks about the space station. In the summer of 1982, at the request of NASA, the Board brought together about 30 recognized experts from various user communities to determine what practical uses a space station or a space platform might serve and, if it were to be developed by NASA, what requirements should be placed on the design of a space station to make it more useful.

The study participants were divided into panels representing user-oriented communities, and that included Earth's resources, Earth's environment, ocean operations, satellite communications, and the materials science and engineering. The report of this study is now ready for publication and should be available in April of this year.

In the meantime, I have communicated the results of the study in a letter to the NASA Administrator, and I reported the results to the Senate Committee on Commerce, Science, and Transportation in November of last year. I would like, in a few sentences, to summarize the results for this committee.

Most observations from a satellite intended to support Earth resources uses, Earth's environmental studies, and ocean operations would require a near-polar, sun-synchronous orbit. This implies the use of a large unmanned space platform in a low, near-polar orbit. The utility of such a platform would be enhanced by the availability of a manned service station which could be used to service, repair, and if necessary replace instruments on the platform, to recalibrate those instruments, and to resupply the expendables such as cryogenic coolants and propellants used for attitude control and station-keeping.

A low Earth orbit space station would provide little benefit directly, however, for the geostationary communications satellites in the near future. However, it is possible that the manned station could serve as a fuel depot and a base of operations for launching larger communications platforms up to synchronous orbit. A low orbiting space station could also be used for conducting some classes of communications experiments, such as the deployment and evaluation testing of a very large antenna. Our materials science and engineering panel envisioned a space station that would provide, in miniature, a laboratory staff with technically trained operators, similar in some respects to a materials laboratory on Earth.

In summary, our studies indicate that a manned space station program which included a remote sensing platform in near-polar orbit could be useful and beneficial to the many space applications interests. However, we feel that the effective utilization of a space station would require significant resources beyond those required for development of the space station alone. There would need to be an equal commitment to the timely development of instruments and payloads for use on the station and the remote sensing platform. In conclusion, we believe the space station as now conceived can eventually prove to be one of the Nation's most important undertakings in space.

Mr. Chairman, that concludes my statement, and I would be happy to answer any questions.

[The prepared statement of Mr. Harter follows:]

Statement by

George A. Harter
Chairman, Space Applications Board
National Research Council

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
U.S. House of Representatives
February 8, 1984

Mr. Chairman and Members of the Committee:

On behalf of the Space Applications Board of the National Research Council, I would like to thank you for the invitation to participate in this hearing. My purpose is to present, as you requested, the current thinking of the Board on the NASA space applications program.

My name is George Harter; I have been a member of the Space Applications Board since 1981 and have been chairman since December 1982. I am presently employed by TRW Incorporated, Los Angeles, California, as Vice President and Assistant General Manager for the Electronics and Defense Sector. Since joining TRW in 1957, I have held a number of technical and managerial positions in the spacecraft and electronics fields. A brief biography is attached to this statement.

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Mr. Chairman, your letter of January 4, 1984 asks that we address three subjects:

1. NASA's space communications research program,
2. NASA's program of materials processing in space, and
3. The place of the applications program in the "Mission of NASA".

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transmission techniques. This program was previously referred to as the "30/20 GHz" program. However, the emphasis should be less on the frequencies (although it is important to open them up to commercial exploitation) and more on the technology that is being developed. At this stage, the program appears ready to enter an intensive period of test and development that will culminate in flight testing of the relevant technology. We hope these facts will be considered as NASA sets its future priorities.

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in materials sciences and technology. In addition, NASA has begun to use the shuttle as a vechicle for pilot testing of materials processing in space. We believe this program is proceeding well and is properly funded. As I will point out later, materials processing may be one of the more important uses of a future space station.

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NASA; and what requirements should be placed on the design of a space station to make it more useful. The study participants were divided into panels representing user-oriented communities, i.e., earth's resources, earth's environment, ocean operations, satellite communications and the materials science and engineering. The report of this study is now ready for publication and should be available in April of this year. In the meantime, I have communicated the results of the study in a letter to the NASA Administrator, and I reported the results to the Senate Committee on Commerce, Science, and Transportation in November of last year. I would like, in a few sentences, to summarize the results for this committee.

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Mr. Chairman, this concludes my statement.

MWR/vb

2/6/84

GEORGE A. HARTER

Vice President and Assistant General Manager
Electronics and Defense Sector
TRW Incorporated
Los Angeles, CA

Mr. George A. Harter has been appointed recently as vice president and assistant general manager, Electronics and Defense Sector of TRW Incorporated. He was previously corporate vice president for Planning and Investment in the Cleveland, Ohio Office of TRW.

Mr. Harter has been president and assistant general manager of TRW's Defense and Space Systems Group, an organization employing more than 14,000 people serving military and aerospace markets.

He joined TRW in 1957 and has held a number of key technical and managerial positions in the spacecraft and electronics fields.

He became vice president and general manager of space vehicles Division in March 1971. The division designs, develops, and manufactures unmanned satellites for the Department of Defense, National Aeronautics and Space Administration, and commercial customers.

He later served as vice president and general manager of the Electronic Systems Division, where more than 3,000 engineering, scientific and manufacturing personnel perform applied research, hardware design and development, fabrication, integration, and test of electronic systems.

Mr. Harter has authored a number of articles related to electronics and space communication systems. He is a past member of the board of governors for the Electronic Industries Association and has served as chairman of the Government Division.

He received a B.S. and M.S. in Mechanical Engineering from Purdue University and an M.S. in Electrical Engineering from Ohio State University. He completed the UCLA Executive Program in Business Management in 1967. He is an associate fellow of the American Institute of Aeronautics and Astronautics (AIAA) and a member of Tau Beta Pi, Pi Tau Sigma, and Sigma XI.

Mr. Harter and his wife Helen live in Torrance, California. They have two children.

Mr. VOLKMER. Thank you very much, Mr. Harter.

I now recognize the gentleman from New Mexico if he has any questions.

Mr. LUJAN. Thank you, Mr. Chairman. Yes, I do.

We went into some depth in discussion yesterday on the ACTS, the advanced communications satellite, and I am still not sure whether the private sector would be capable of moving ahead and developing that technology. After all, you know, Hughes has already decided to go on ahead with admittedly one that doesn't quite have the spectrum that NASA talks about, but wouldn't it be logical to assume that if the needs are there for industry, that they would proceed? After all, they have access to the same technology. Could you explore that for me, please?

Mr. HARTER. Well, I can give you my opinion and what I think is the opinion of the key members of our Board who were involved in or are interested in the communications/telecommunications area.

We think that the on-board switching and the scanning antenna approach, which allows much greater use of the frequency spectrum and conserves that for us in our limited number of slots we have that have access to our domestic utilization, will probably not be developed until at least well beyond when they would be needed if there isn't some effort to promote this program and get the users comfortable with using it.

As you do know, certainly the 30/20 gigahertz spectrum is going to be promoted and used by the Hughes satellite, as they have filed, and that certainly is a great step forward in terms of further use of our limited slots, but there is at least a tremendous increase in what can be done if we can somehow get developed and get into use this future capability.

Mr. LUJAN. What I am wondering is, we have the contractor team which is working with NASA on it, and the members of that team would be the ones that would benefit the most from that technology. Isn't it pretty easy to say, "Well, as long as Uncle is going to pick up the tab, let's move ahead in that direction so we don't have to spend our own money on it."

Mr. HARTER. I would say the common carriers are the ones that are going to benefit, longer term, and I think the only way that they are going to get on board with that technology is through their ground terminals, working into such a capability, to be able to develop and refine their techniques so that they would be comfortable in going that way.

Mr. LUJAN. Are the members of the contractor team sharing in the expense of ACTS, or——

Mr. HARTER. Frankly, I'm not personally too familiar with the whole financial arrangement. Some of my Board probably are, but I am not personally that familiar with it.

Mr. LUJAN. On the space station, although you do mention that we need a manned station as well as a platform, there seems to be a lot more interest in the work, the scientific work, that can be done on the unmanned platform and just using the manned platform for servicing the unmanned, or the space station for servicing the unmanned platform. Is that what I gather from your testimony?

Mr. HARTER. Well, yes. My own view of what is happening is, NASA feels there are more needs to proceed with the inclined-orbit manned capability, and that is not of much use for applications programs, but they have included in their current architecture having a near-polar, sun-synchronous orbit platform with applications sensors which would be good for weather and Earth observation.

Mr. LUJAN. Would that require a Sun-synchronous orbiting manned station?

Mr. HARTER. No, but a capability to actually service and repair that we think is very important, and as I understand the current thinking of NASA and their current design, they will try to use some modular part of the manned station to be that unmanned platform so they can use commonality of design, but we feel it would have to be serviced by man periodically.

Mr. LUJAN. So you are not really talking about two different structures. You're talking about an extension.

Mr. HARTER. Well, that's my understanding.

Mr. LUJAN. Either way you want to look at it, either extending the platform to a manned station or extending the manned station with a platform.

Mr. HARTER. That's my understanding of what they're planning right now.

Mr. LUJAN. Yes, and——

Mr. HARTER. And that's one of the requirements we felt we placed on them, is if they want to really utilize the so-called space station program for space applications and needs, that they are going to have to implement some sort of a polar, near-polar orbiting satellite of the type that——

Mr. LUJAN. So we're not really talking about a manned and unmanned. We're talking about a space station with both capabilities.

Mr. HARTER. That's my understanding, yes, and that's what we're recommending.

Mr. LUJAN. Why do we keep drawing that distinction? It would seem to me that if you built a manned station, that you hang a satellite onto it or whatever and then that becomes just like if you had it on an unmanned platform. Why this——

Mr. HARTER. Why the manned?

Mr. LUJAN. I keep hearing this distinction between the two.

Mr. HARTER. Well, it seems to me obviously you could go ahead with an applications near-polar orbiting platform with instruments without, you know, going ahead with a full-blown manned space station——

Mr. LUJAN. Yes.

Mr. HARTER [continuing]. But I think if you are going ahead with a space station, it's easy, relatively easy, to incorporate this as part of the total planning for that and perhaps by your commonality of design, perhaps lower your total cost.

Mr. LUJAN. Yes.

Mr. HARTER. But certainly we have indicated to NASA right from the start that they certainly couldn't justify the space station based upon the applications program, and probably no other single element of what they're trying to serve.

Mr. LUJAN. Well, that's never been the intent of NASA, has it?

Mr. HARTER. No, no. That's right.

Mr. LUJAN. At least not in anything that I've——

Mr. HARTER. And so they thus far have, it seems to me, tried very hard to accommodate the applications community in their overall plans and see that they are satisfying what we think would be our needs during the next 20 years or so.

Mr. LUJAN. Well, I just wondered why that distinction was being drawn between the two when it just makes sense that you have some capability of hanging some instrument on it or on a platform or whatever it may be, and I just haven't been able to understand why the distinction, but there really is none, is what you're saying.

Mr. HARTER. That's right.

Mr. LUJAN. Thank you, Mr. Chairman.

Mr. VOLKMER. The gentleman from California, Mr. Dymally.

Mr. DYMALLY. Thank you very much, Mr. Chairman. I'm glad to see Mr. Harter here today.

Mr. Harter, in your review of NASA's programs through the Applications Board, did you have occasion to study the global positioning system satellites designed for the Caribbean?

Mr. HARTER. No. The GPS?

Mr. DYMALLY. Yes.

Mr. HARTER. No, we have not looked at that.

Mr. DYMALLY. Mr. Chairman, I hope I'm not digressing but with your permission I just want a couple of minutes to focus on something very important, and I hope Mr. Harter would take it up from there.

In 1980 NASA and cooperating agencies began a study of the use of the DOD global positioning system satellites for mapping regional crustal strain rapidly and economically. In fiscal year 1984 NASA agreed to reallocate $2 million to acquire several GPS units for use in a pilot project to measure crucial deformation related to earthquakes in the Caribbean and for similar studies in South America and the eastern Caribbean—eastern Mediterranean, sorry.

However, the money to carry out the Caribbean, South American, and Mediterranean projects—$6.5 million—was deleted by OMB from the NASA budget. If this money is not restored by Congress, existing agreements with several foreign countries will be canceled, negotiations with other countries will be broken off, and the Caribbean and South American measurement campaigns will be deleted from the program—and this is the critical part for us, Mr. Harter—the measurement of crustal strain in California using GPS systems will be set back several years.

Mr. Chairman, I bring this to the committee's attention because last year, with the permission of the Foreign Affairs Committee, I attended a worldwide conference on earthquakes in Hamburg, West Germany, and knowing of my interest in the Caribbean, this item was brought to my attention then, in August of last year. Now I come to find out that a very significant part of what could be great, great visibility for us with the Caribbean Basin Initiative has been eliminated. What we are suggesting to the Caribbean and Central American countries and South American countries is that our interests are primarily military, and this is a critical part, it seems to me—or could be—of the CBI.

So, Mr. Chairman, with your permission I would like to enter into the record a more lengthy statement I have. I used Mr. Harter's presence here to zip this in, because I want this committee and NASA in its authorization to look at this program. So now back to more relevant questions that you raised, Mr. Harter.

Mr. VOLKMER. Without objection, if you do have a statement I will insert it, have the reporter insert it in the record at this point.

[The prepared statement of Mr. Dymally follows:]

1. The NASA Crustal Dynamics Project (CDP) was initiated in 1980 to measure and analyze earth crustal movement and deformation (using satellite laser ranging and very long baseline interferometry) for studies of the solid earth and to increase understanding of earthquake mechanics, particularly in the U.S.

2. The primary emphasis of the CDP is to conduct research in tectonics of the western U.S. and Alaska and to study global plate motion. In support of these studies measurements were required in South America, the Caribbean region and the Mediterranean and were included in Project plans.

3. In response to a NASA Announcement of Opportunity proposals were received and accepted from U.S. investigators and 14 countries. International agreements were concluded with England, France, FRG, The Netherlands, Italy, Switzerland, Sweden, Canada, China, Japan, Australia, Mexico, Venezuela, Bolivia, Peru, and Chile. (Additional agreements are now pending with Austria and Israel)

4. In FY 1981 and 1982 Administration budget reductions (25% each year) forced postponement of studies in the Mediterranean, Caribbean and South America and extension of the Project by two years.

5. In FY 1984, $4M was requested to restore these activities. This was declined by the OMB. Although the $4M was resubmitted by NASA, the OMB position was not altered.

6. In January 1983 as a result of a special plea to the NASA Administrator, he decided to reallocate $2M of FY 1983 funds for these studies with a commitment for follow-on year funding.

7. The reallocation, which required congressional committees' approval, was initially contested to by the Chief Staffer of the House Appropriation Committee (Dick Malow). It was resubmitted to the Congress as part of the NASA operating plan for Fiscal Year 1984. Since no further objection was noted, NASA proceeded with the reprogramming.

8. In the meanwhile, the European Community formally constituted as the Wegener Consortium negotiated agreements with Tunisia, Egypt and Turkey for measurement sites in these countries whereby German, Dutch and U.S. laser ranging systems would be located in the Mediterranean in 1985 and and sought funding from their Governments for the German and Dutch systems to work cooperatively with U.S. systems in Bolivia, Peru and Chile.

9. In the FY 1985 budget $6.7M was requested by NASA to continue these studies. The original request was denied by the OMB and was not resubmitted by NASA.

10. The requested restoration of $6.7M in Fiscal Year 1985 to the Geodynamics Program is needed to:

    a. Initiate research of crustal deformation plate motion in the Caribbean basin area, including Central America, using the DoD Global Positioning System and involving 14 countries - $3.2M;

b. Conduct studies of crustal deformation in South America with Bolivia, Peru and Chile using satellite laser ranging - $3.0M; and

c. Study regional crustal deformation and plate motion in the Mediterranean area jointly with eight countries - $0.5M.

11. The Caribbean research would be conducted cooperatively with the following countries: Dominican Republic, Jamaica, Haiti, Ecuador, Costa Rica, Honduras, Guatemala, Trinidad, Barbados, Venezuela, Colombia; and with territorial areas including Puerto Rico, Grand Turk, St. Croix, Cayman Islands, Navassa Island, and Aruba.

12. Funding is specifically required for:

a. JPL to develop the GPS geodetic receivers and to support observations in the Caribbean and Central America, and

b. GSFC to develop a fourth highly mobile satellite laser ranging system for the South American and Mediterranean studies and to increase operations of existing laser systems in support of the mobiles.

13. In view of the scientific importance of these studies to the understanding of global tectonics and in particular earthquake mechanism in the U.S. and to avoid embarrassment both to the U.S. and other countries resulting from cancellation of international agreements, the baseline CDP activities have been restructured to allow continued support of the Mediterranean research. This still leaves no funding for the planned Caribbean and South American studies.

14. For South American a minimum level program in FY 1985 is still possible and NASA is prepared to continue this effort.

15. Without additional funding and the assurance of follow-on year funding stability, continuation of the Caribbean studies will have to be terminated. This is indeed unfortunate for several reasons:

a. The tectonics of the Caribbean are as complex as any in the world and have strong social and economic significance.

b. The demonstration of the GPS usage in the Caribbean is of paramount importance to future studies of regional deformation. This was identified by the NAS Committee on Science, Engineering and Public Policy (COSEPUP) as one of five major earth science initiatives (Space Geodesy) and presented to Dr. Keyworth (OSTP) last year.

c. The U.S. would lose an opportunity to develop favorable international relationships with most countries of the Caribbean and Central America at minimum costs to us and them.

16. To restore the planned activities in the Caribbean region and in South America a total of $4.0M is required in FY 85.

Mr. DYMALLY. Thank you very much. I hope OMB, NASA, and this committee can look at that as we proceed with the authorization.

Mr. Harter, assuming NASA moves ahead with ACTS but limits it to a ground test program only, what tangible benefits will be gained or lost as compared to a flight program?

Mr. HARTER. Well, let me say what I think would be lost. Frankly, I don't know that they have detailed out exactly what they would do in a ground test program. At least they haven't made us aware of it, and my impression is they still have to think that out because that's a fairly new concept.

But we feel that a laboratory demonstration on the ground would really not substitute for a flight evaluation which would involve the many common carriers who would plan to participate in the ACTS program at that time. It seems to us that the users need to work with this new signal-switching and beam-scanning system in a real life situation in order to evaluate their own interfacing techniques and to establish enough confidence for themselves for moving ahead with operational development.

So I guess, in a nutshell, we feel that kind of a laboratory demonstration within a NASA laboratory would really not do what was originally intended by the ACTS program—to have broad participation, and in real life situations, so that they can really learn how to use this new technology with their other interfacing systems.

Mr. DYMALLY. There was a story in the Washington Post recently, but I heard this over the National Public Radio system, that the space is becoming crowded with satellites, at least this spot of the world, not in the Pacific islands. Do you think that's going to be a real problem for us as we launch more satellites in this part of the hemisphere?

Mr. HARTER. Oh, well, certainly. I think it's generally accepted that we're going to have a real problem in the not too distant future with not having enough space at geosynchronous orbit to put enough communications capability there to satisfy both our needs but the expanding needs of the Western Hemisphere, which includes South America, who are going to insist upon their fair share of the space up there. So I think we have to move ahead with much more efficient utilization of those slots that can actually, physically see our country or we are going to be in deep trouble in terms of being able to have enough satellite communications in the future.

Mr. DYMALLY. Recently we have had some unsuccessful launchings of satellites—and again, back to National Public Radio, which I recommend to everyone to listen to. As a layperson, what I hear being said by the National Space Institute, NASA did their job. They were not responsible for the failure. All they had to do was to shoot it out. The failure came from the manufacturing. Could you explain that for a layperson like me to understand?

Mr. HARTER. Well, I don't have any inside information. I just watch the radio—listen to the radio and watch TV, also, but it's my understanding that the satellites were ejected from the shuttle in perfect order and that there was a problem in the injection rocket that was used, the solid rocket which was used to propel the satellites on up to synchronous orbit. Now what that failure was, I have

no insight, although it's something that has happened in the past. Very unfortunate that we haven't worked those bugs out of those solid rockets, and particularly to lose two at one shot, it's very unfortunate.

Mr. DYMALLY. But NASA's responsibility was just to shoot it. They had nothing to do with——

Mr. HARTER. That's my understanding, yes, and I believe that to be true. I don't think it was any failure on NASA's part at all.

Mr. DYMALLY. Good.

Thank you very much, Mr. Chairman.

Mr. VOLKMER. Thank you very much, Mr. Dymally.

I would like to get back to the ACTS, and the question—and you have answered the question, Mr. Dymally, that I had also as to ground testing—as I understand, yesterday we had testimony from Dr. Edelson and he seemed to believe that they would be able to do testing on such things like the on-board switching and the processing and the things that are different in the ACTS program than the Hughes program, through ground testing, satisfactorily to prove up the technology. Then he says with that, then, that the private sector would pick up that technology and use it in space.

Now you have added one more thing to this which none of us asked him about yesterday, and that is the user-community with ground-based stations not having any prior utilization. In other words, who is going to take it and put something up there if nobody is going to want it down here? Is that correct?

Mr. HARTER. I think that's the crux of what I'm saying. I have no doubt that you can prove that the equipment will work in the laboratory, but without the involvement of the users and getting them to both understand how to use it and develop their own equipment to interface with it—which I think would be very difficult to even interest them in doing it up in a laboratory in Cleveland—that I just think that we are missing the point of the user involvement here, which has been kind of a common problem in the past in many of our applications areas. NASA develops something but they don't really bring the users along to pick it up and take it.

Mr. VOLKMER. The other question that I have, the area, it relates to where we are as far as land remote sensing, and you address this in your statement but I was just wondering about when it would be—what, this summer sometime?—when we would have some idea from the Board about a possible strategy as far as remote sensing is concerned.

Mr. HARTER. Well, realistically I would think maybe the fall. This is a very difficult question that we're trying to address, and I don't underestimate how hard it's going to be for us to try to bring our Board to some resolution as to what we think ought to be done, but hopefully in the fall we can have this.

Mr. VOLKMER. Well, in that will you be addressing the question of privatization, in other words, the capability of privatization?

Mr. HARTER. Yes.

Mr. VOLKMER. And also the question of continued involvement by NASA in research——

Mr. HARTER. Yes.

Mr. VOLKMER [continuing]. And analysis or research and development of other possible remote sensing instrumentation?

Mr. HARTER. That's exactly what we wish to do, and we are concerned that because of this whole issue of privatization, that the funding and the effort within NASA, even in technology development, is falling off very fast. We're concerned that there just won't even be—we won't maintain any kind of a lead here in the advanced technology over the other countries who are pursuing this very much at this time.

Mr. VOLKMER. Now we will have the next satellite being launched, I believe it's around the first of March, and then there is a proposal, I think, being presently studied of picking up in the next couple of years the satellite that just went out, Landsat D, and bringing it back for possible repair and then putting it back up again, so if that could happen we would have time to maybe work on something, would we not?

Mr. HARTER. Yes. I think both that next satellite has to be very successful and long-lived, and we have to be successful in that recovery to give us any hope of maintaining some continuity in a U.S. capability here over the next few years.

Mr. VOLKMER. But you're also concerned about the continuity in the research in the total field.

Mr. HARTER. Yes, that's right.

Mr. VOLKMER. Technology development.

Mr. HARTER. That's right, very much so.

Mr. VOLKMER. I have no further questions.

The gentleman from Washington, Mr. Chandler. Do you have any questions?

Mr. CHANDLER. At the risk of asking a question that has already been asked——

Mr. VOLKMER. Go ahead.

Mr. CHANDLER [continuing]. And I apologize for being late—I was quickly trying to read your statement and I noticed your comment that you feel that a space station would require not only the resources to build the thing itself, but then you say an equal commitment to the timely development of instruments and payloads for use on the station and remote sensing platform. Have we budgeted enough? Are we being realistic about what we're proposing at this point?

Mr. HARTER. Well, it's a little difficult for us to analyze the total budget for that space station. It's very complicated. All we can say is that they have included line items in there to do this. So we are very sensitive, as a matter of fact, and carefully point that out, that we would be very concerned if there isn't enough money budgeted for the total program, because obviously the space station itself will take top priority and it would be a catastrophe for the applications program if there were not enough funds in total and that had to be deferred because of greater needs on the space station program.

Mr. CHANDLER. That's my only question.

Mr. LUJAN. Do you think that's the case with the budget now?

Mr. HARTER. I frankly—I have no reason to think it is the case, but I must say that I don't think any of us either have—or perhaps don't even have the capability of analyzing those tremendous costs over the next few years or next number of years to be able to reach a conclusion on that.

Mr. LUJAN. Well, we are sensitive about that because th[illegible] is, you know, one of the concerns from scientists, that in forging ahead with the station, that science suffers. We certainly want to be sure that we're not doing that.

Mr. HARTER. Well, it seems——

Mr. LUJAN. But you're satisfied with what's there now, that we can proceed both with the station and with the science associated with it?

Mr. HARTER. Yes, and I feel we must in a management sense keep tabs on that as the program goes along, to make sure that we don't lose sight of that need.

Mr. LUJAN. Thank you.

Mr. VOLKMER. Mr. Lujan, thank you, and thank you very much, Mr. Harter. I appreciate your being here today. You have been very helpful to the subcommittee.

Our next witness will be Dr. Elizabeth L. Young, president of the Public Service Satellite Consortium.

Dr. Young, your statement will be made a part of the record in full, and you may either summarize or review it in total, however you so desire. You may proceed.

STATEMENT OF DR. ELIZABETH L. YOUNG, PRESIDENT, PUBLIC SERVICE SATELLITE CONSORTIUM

Ms. YOUNG. Thank you, Mr. Chairman. I will summarize it, and I do have a written summary prepared for the committee with a couple of charts and addenda that I would like entered into the record, and which I will discuss as a part of the statement.

The Public Service Satellite Consortium is pleased to appear again before the subcommittee today to discuss NASA's work, specifically in communications satellite research and development. Our members, all nonprofit public service agencies and institutions—and a list of those is appended to my formal statement—have been pioneers in the use of satellite technology, and we have benefited from NASA's work over the last decade during such programs as the application technology satellite or ATS program and the joint United States/Canadian endeavor called the communications technology satellite or CTS.

Our particular concerns at this time are twofold: First, that NASA keep as a high priority the strong research and development program it has developed in the communications satellite field. The successes of this program are many and have resulted in direct monetary gains to the Nation as a whole, yet for some reason, gentlemen, we seem to revisit this area at least once every decade. Inevitably the answer is that the program should continue and be strengthened, but the sometimes extended policy debate tends to weaken the very programs that are ultimately deemed to be beneficial.

At this time, NASA's communications division is doing commendable work in the search and rescue area, in developing advanced technology for a mobile satellite experiment in concert with industry, and once again with Canada, and in planning for what will clearly be the advanced technology needed for domestic communications satellites in the next decade.

This brings me to the PSSC's second major concern at this time, the advanced communications technology satellite program, or ACTS. The ACTS program is a direct outgrowth of an assessment of the need to advance the state of satellite communications technology in order to meet the expected demand for services in the 1990's. It also responds to the threat of foreign competition for systems to serve the U.S. domestic market.

The program content resulted from an intensive interaction between Government and industry, and involved not only systems suppliers but the service suppliers or the carriers as well. The critical technologies embodied in ACTS, as well as the system functional capabilities, underwent review and critique by all who were willing to participate in the process of planning this advanced R&D effort of NASA.

As a result, the program has received strong support from a broad cross section of the industry and user communities. As a normal part of the PSSC's role, we interact with many members of both the supplier and carrier industry, and I have certainly experienced this support firsthand. NASA should be commended on its continuing effort to involve all interested parties in the process of planning and implementing the overall ACTS program.

Benefits to be derived from the ACTS program are already evident. The presence of NASA as a catalyst in the technology development process has already resulted in significant advances in technology and, perhaps more importantly, a preception that the advanced communications capabilities embodied in ACTS are realizable in future commercial systems.

The value of ACTS is twofold. First, the flight experiment will allow the technology developers opportunity to establish the performance of the advanced technology in a real operational environment. Second, it will allow both service suppliers and users to experiment with the new technology so that they can become familiar with and develop a confidence in its use and assess its performance and cost for their own particular applications.

This wide accessibility to ACTS technology and functional capability will not be available through any other mechanisms, certainly not with military systems, which is an area that the committee requested I comment on. With respect to military systems, considerable discussion has centered on whether DOD communications satellite programs could provide an alternative to the NASA technology flight experiments. The Milstar program is spoken of most frequently in this regard.

Milstar is a DOD program designed to provide jamproof global communications for mobile strategic and tactical forces. To accomplish this, several satellites will function autonomously to interconnect air, land, and sea units. These communications will link a small number of users with a system featuring high survivability and security. Milstar will be an operational war fighting communications system in support of military operations around the globe.

The ACTS system, on the other hand, is an experimental system designed to develop the high-risk technology envisioned as necessary for future civilian satellite communications. ACTS is intended to develop and establish the technology required to enable further growth in and more effective use of the frequency spectrum. This

technology is intended for use in high-volume commercial telecommunications systems serving many and diverse users. ACTS technology must be designed to be applicable to economically competitive commercial systems. Milstar, on the other hand, while it must be cost effective, is not driven by having to be economically competitive.

Both ACTS and Milstar operate in the 30/20 gigahertz frequency band, although technically Milstar really operates in the 40/20 GHz band. The differences in the missions, however, of these two programs lead to the differences in their functional requirements and therefore in their technologies. For example, individual terminal capacities are significantly different.

ACTS, since it is intended to support the future growth in commercial telecommunications, would support high-capacity terminals and I have, Mr. Chairman, a more detailed description here. With your permission that will go into the record.

At the generic technology level ACTS and Milstar do draw from the same technology base which was developed jointly by NASA and DOD. Now there has been another recent development which has led to considerable discussion with respect to ACTS.

In December 1983 the Hughes Communications Galaxy, Inc., filed with the Federal Communications Commission for authority to operate two Ka band communication satellites for supplying U.S. domestic services starting in 1988. Using the Ka band, or 30/20 gigahertz, signals are sent up to and are received from the satellites. Current satellites in the United States use C band—6/4 gigahertz—and Ku band—14/12 gigahertz—frequencies.

Japan is the only country currently operating Ka band satellites. Its first generation Ka band satellites were launched in 1977. It has a second generation already operating and a third generation scheduled for launch at approximately the same time that ACTS would go up.

The Hughes satellite system will use all of the available Ka frequency band width, which is about five times that available at C and Ku bands. Its capacity will be about a factor of four times that of the largest satellite in service today. Two satellites are planned to be placed in orbit 2° apart—one is a backup for the other—to provide services over a 10-year period.

To a large degree the Hughes proposed system is an extrapolation of current frequency division multiple access technology to Ka-band frequencies. The system will utilize current state-of-the-art integrated circuit technology for switching circuits on board the satellite.

Much discussion has centered around the notion that the presence of the planned Hughes satellite negates the need for the NASA ACTS program. I would like to provide to the subcommittee today, as a part of my testimony, an analytical comparison of the Hughes galaxy system and the intent of the ACTS program. In part, the comparison is one of apples and oranges since Hughes is proposing merely what two satellites would do as satellites, whereas NASA has planned a complete program which would include experimental ground stations and user experiments built into the program.

If the technology content were comparable and wide access to that technology were available, as with ACTS, then the obvious conclusion would be that the need for the ACTS flight program has been eliminated. However, upon examination of the Hughes filing, it is evident that their proposed system is responsive to their perspective of what the marketplace will need in 1988, and not necessarily responsive to the technology needs of the 1990's.

The Hughes filing is an important event and does represent a bold move by Hughes Galaxy, Inc. It should not, however, in our opinion, be confused with the tenets of the ACTS program nor considered to be a substitute to attain the ACTS goals established by NASA in concert with the industry. There are significant differences in the technology planned for each system, as there should be. Hughes is responding to operational service needs, while ACTS is aimed at advancing the state of technology to allow options to be exercised in the future which will not be available if the program ends.

In summary, the ACTS technologies are different from those technologies required by the Hughes system and they require significantly greater advancement beyond the current state-of-the-art. The ACTS technologies are designed to provide very large capacity systems which utilize the frequency spectrum and orbital arc in a very efficient and conservative manner, provide a wide variety of services, minimize spacecraft weight and power to increase cost effectiveness, have a large degree of circuit routing flexibility, and provide wide area coverage within the continental United States. These technologies will enable industry to build the advanced communications satellites of the 1990's.

A further and most important feature of the ACTS program is that it will allow for industry and user community experiments, as Mr. Harter has also noted. I have attached to my summary statement today two lists of potential experimenters, one representing primarily industry and Government and one representing primarily public service entities that have over the past year indicated an interest in becoming experimenters during the life of the ACTS program. Historically, such experiments have benefited not only the experimenters—leading them to a state of readiness to adopt the new technology for ongoing operations—but the Earth station manufacturers and carriers have benefited as well.

It was our experience, for example, in conducting experiments on the ATS-6 and CTS programs, that over half of those organizations who were experimenters on those two satellites ultimately became commercial users of existing commercial domsats today. That was all along a part of NASA's plan for technology transfer, and in our experience it worked spectacularly well.

We are now facing a decision reminiscent of that decision in 1973 which drastically reduced NASA's R&D activities in satellite communications technology and removed flight experimentation from the NASA space program. We experienced a stagnation in high-risk technology advancements, and thereby encouraged entry into this U.S.-dominated field by Europe and Japan. While we debated the wisdom of the NASA decision a decade has passed.

While the NASA advanced communications R&D program slowed, Japanese and European efforts and funding accelerated.

Exclusive of the Soviet Union, the world's first domsat prime contract outside of the United States was recently awarded to Aerospatiale of France for the Arabsat system. The Japanese, as I mentioned, already have launched communications satellites for tests in both Ku and Ka band. Although the first series of satellites in this program was bought from U.S. industry, several of the key components and subsystems were developed and provided by Japan, and it is planned that all subsequent models will be developed and produced in Japan.

It is also noteworthy, I think, that the Japanese have become the leading supplier of Intelsat Earth stations and are likely to take the world market lead in the sale of TV sets designed specifically for direct broadcast satellite reception. It is clear that U.S. industry no longer dominates the entire satellite communications market. It also appears that both Japan and Europe have decided to forgo major competition at C and Ku band, and to leapfrog those technologies by concentrating on the 30/20 GHz band and associated advanced technology.

The continued erosion of the U.S. position will be accelerated by what appears to be the current decision of NASA. Ground testing does indeed contribute to technology development. However, the results will not have the impact of a flight system experiment. The planners and operators of future systems must make a judgment with regard to the technical readiness of any new concept, and in particular those new concepts which dramatically change the way the business is to be conducted.

As history has shown, private companies are not afraid to take risks when the extent of the risk is known. Ground testing of flight components and systems falls short of establishing confidence in the readiness of the technology for operational system implementation. The need for flight testing cannot necessarily be proved. As in many decisions, we must rely on lessons learned from history, the judgment of those who are knowledgeable and competent in the field, and our own commonsense.

We must also consider the possible consequences of not following through with the ACTS flight experiment. It is not at all clear that we can afford to be wrong in this fast-moving, highly technical field. We must decide now whether the cost of ACTS is justified by the expected benefits, without the help of hindsight. Have all those who during the past 5 years closely followed the ACTS program development and continually supported the need for a flight experiment program been in error, or is the press of budgets within NASA going to cause history to be repeated?

By reopening the debate on this issue we have already delayed the schedule by a minimum of 6 months. As a consequence, the funding required in fiscal year 1985 to continue the flight program initiative would probably realistically be about half of the amount originally required. It is my understanding, by the way, that the total program cost as established by NASA would not be materially affected by this slip except for inflation effects. In our currently inflationary environment the impact would be quite small, perhaps $6 million over the length of the entire program. I think the difficult question that must be answered is: Can we afford not to continue the ACTS initiative?

And, Mr. Chairman, before I conclude my formal statement, may I take the liberty of responding in a little greater detail to two of the questions that were asked of Mr. Harter? First of all about cost-sharing in the program, it is my understanding that those organizations and entities who had subcontracts and currently are anticipating a prime with the subcontracts on the ACTS program, had it moved toward flight, have already contributed something on the order of $140 million toward the program in cost-sharing. This came as a direct result of OMB's request 2 years ago when the program was being debated that there be tangible and obvious cost-sharing, and that has been done to date. Our initial estimates are that there would be some $50 million in additional cost-sharing by the time ACTS is launched, including additional cost-sharing by the contractors and by those experimenters whom I have listed in the addenda to my testimony today.

The second point that I simply wanted to make, and it relates to Mr. Dymally's question about the orbit-crowding, is that no matter which studies we look at, whether they are relatively conservative or quite optimistic about the future of satellite communications, everyone seems to concur—the carriers, independent researchers, NASA itself, and certainly those of us who work in the industry—that the crowding in the spectrum, even with 2° spacing and some use of advanced technology, is going to be acute.

In last months issue of Private Cable, which is a magazine that covers this area, there was a summary of a report by a group called the International Resource Development, Inc., and independent consulting firm, which said, "Transponder demand is growing just a little bit faster than available transponders," and their estimates were of the requirements for Earth station satellites, transponders, and additional hardware through the year 2000. This report tended to support all of the other reports that we have seen, recognizing that there is always some margin for error.

That does conclude my formal remarks, and I would be happy to respond to questions.

[The prepared statement of Dr. Young follows:]

PREPARED STATEMENT OF ELIZABETH L. YOUNG, PRESIDENT, PUBLIC SERVICE SATELLITE CONSORTIUM AND SERVICES BY SATELLITE, INC.

INTRODUCTION

The Public Service Satellite Consortium has been asked to testify on the subject of NASA's space communications program, and I thank the Subcommittee for this opportunity to do so.

The PSSC has been involved in assisting its members and others with appropriate uses of communications satellites and related technologies since 1975. (A current PSSC membership list is attached.) Our goal is to build a user community that can take full advantage of state-of-the-art technologies for public service communications requirements. We work closely with the established carriers and others in the satellite industry to afford services to our members and other clients. At the same time, a substantial part of our mission is to ensure that our members will have opportunities to experiment with new developments in satellite communications.

The ACTS program is a direct outgrowth of an assessment of the need to advance the state of satellite communications technology in order to meet the expected demand for services in the 1990's. It also responds to the threat of foreign competition for systems to serve the U.S. domestic market. The program content resulted from an intensive interaction between government and industry and involved not only system suppliers but the service suppliers (satellite carriers) as well. The critical technologies embodied in ACTS as well as the system functional capabilities underwent review and critique by all who were willing to participate in the process of planning the advanced R&D effort of NASA. As a result, the program received and still has strong support of a broad cross section of the industry. As a normal part of the PSSC business, we interact continuously with many members of both the supplier and carrier industry and I have experienced this support first hand. NASA should be commended on its continuing effort to involve all interested parties in the process of planning and implementing the overall ACTS program.

It is apparent to those of us in this highly competitive communications industry that the application of advanced technology is the way in which the increasing demands for satellite services will be met. The recent flurry of filings before the FCC for satellite orbital positions support the general concern that saturation of the available spectrum is imminent. Not only must we consider looking to new frequencies for relief

but we must insist on using this resource in the most efficient manner possible. This has been the essence and thrust of the NASA ACTS program with the expectation that the technologies being developed will allow effective and efficient expansion of satellite services in the 1990's.

The FCC is currently faced with the problem for the first time of having many more applications for new satellite systems than can be accommodated in the remaining orbital arc at both C-band and Ku-band frequencies. ACTS related technologies cannot help in the current dilemma; however we must allow for continued growth in the use of satellite services and must not delay or defer the needed technology advancements to preclude a recurrence of this type of problem in the future. Delays have already occurred in the ACTS program and a major delay in establishing the maturity of the needed technology is imminent as a consequence of the recent NASA decision. A launch of ACTS was scheduled for 1988 which would have allowed the results of the flight experimentation to impact operational system designs planned for flight in the early 1990's. Delays or elimination of the ACTS effort will of course have a direct impact on the systems to be implemented in the 1990's.

HISTORY AND BACKGROUND

NASA supported and sponsored communications satellite technology development in the late 1950's and early 1960's which was instrumental in the rapid growth and early dominance of world satellite markets by U.S. industry. The SYNCOM program (1960-61) in particular, demonstrated the practical feasibility of geostationary orbit operations. It led directly to the establishment of the Communications Satellite Corporation (COMSAT) in 1963 to exploit the commercial applications of that early technology. Since then we have seen a rapid increase in the use of communications satellites. NASA, in essence, provided the "seed money" which enabled U.S. industry to achieve a dominant world position for satellite communications at C-band. Indeed, satellite communications represents the single best and most successful example of technology transfer in the entire history of NASA.

NASA sustained a strong program in satellite communications technology development through the middle 1960's and early 1970's. Six experimental Application Technology Satellites (ATS) and one experimental Com-

munications Technology Satellite (CTS) were developed and launched. These systems demonstrated several innovations including electronically despun antennas, VHF and L-band communications to aircraft and ships, repositioning and station-keeping in geostationary orbit, direct-to-home TV broadcasting, pioneering the opening of Ku-band to commercial operations and a wide range of component and subsystem technology improvements.

In 1973, NASA's satellite communications program was drastically phased down. Since then, the once dominant position of U.S. industry has been both eroded and even by-passed in some areas. Both Japan and Western Europe perceived the phase-down decision as an opportunity. Their funding for communications satellite technology rose sharply in approximate synchronism with the NASA reductions. But the major thrust of these foreign programs was not directed at head-on confrontation with the established U.S. industry positions in C- and Ku-band. Instead, both Japan and Western Europe recognized that the real opportunity lay in the new 30/20 GHz or Ka frequency band and associated advanced technologies. In that band U.S. industry had neither an established position nor visible plans to reach such a position. By being first in the development and early demonstration of that technology, Japan particularly, expects to establish a dominant market position in exactly the same manner that U.S. dominance was established at the C and Ku-bands.

Recognizing the growing strength of foreign competition and the eroding position of U.S. industry, several committees and independent technical organizations recommended during the mid-1970's that NASA resume communications R&D. That step was taken in 1978.

In 1978 and 1979 detailed assessments of the future demand for communications satellite capacity were conducted for NASA by the U.S. communications industry. Their studies predicted a growing demand for satellite communications services which would exceed the capacity available using current frequency bands and existing technology by about 1990. The solution to this predicted shortage (which is now evident in the Americas region) lies in the introduction of new technology to improve spectrum utilization in general, and in the opening of the next available frequency band at 30/20 GHz to commercial use in a spectrum efficient manner. The critical issue is developing the appropriate technology that allows use of the new band and improvement in the use of existing bands (C-band and Ku-band) such that service demands are met and the U.S. industry remains

dominant in both the current bands and in the new emerging band.

VALUE OF ACTS

Benefits to be derived from the ACTS program are already evident. The presence of NASA as a catalyst in the technology development process has already resulted in significant advances in technology and, perhaps, more importantly a perception that the advanced communications capabilities embodied in ACTS are realizable in future commercial systems.

In this highly competitive industry, risk taking is an everyday occurence. This risk stems primarily from two factors: the uncertainty of the market and the uncertainty associated with the performance and cost of new technology. Because of competition and the difficulty in forecasting the future of telecommunications, market risk is relatively high and a fact of life. Technical risk, however, can be reduced through appropriate R&D. The lasting benefits of a well planned and well executed R&D program is the industry's ability to assess the technical risk of incorporating advanced technology so that an acceptable mix of both technical risk and market risk is possible.

The value of ACTS is two fold. First, the flight experiment will allow the technology developers opportunity to establish the performance of the advanced technology in a real, operational-like environment. And secondly, it will allow both service suppliers and users to experiment with the new technology so they can become familiar with and develop a confidence in its use and assess its performance and cost for their own particular application.

This wide accessibility to ACTS technology and functional capability will not be available through any other mechanism - certainly not with military systems. With respect to military systems, considerable discussion has centered on whether DOD communications satellite programs could provide an alternative to the NASA technology flight experiments. The MILSTAR program is spoken of most frequently.

MILSTAR, or Military Strategic-Tactical and Relay satellite system, is a DOD program designed to provide jam-proof global communications for mobile strategic and tactical forces. To accomplish this, several satellites will function autonomously to interconnect air, land and sea units. These communications will link a small number of users with a system featuring high survivability and security. MILSTAR will be an operational

war fighting communications system in support of military operations around the globe.

The ACTS system, on the other hand, is an experimental system designed to develop the high risk technology envisioned as necessary for future civilian satellite communications. ACTS is intended to develop and establish the technology required to enable further growth in and more effective use of the frequency spectrum. This technology is intended for use in high volume, commercial telecommunications systems serving many users. ACTS technology must be designed to be applicable to economically competitive commercial systems. MILSTAR, on the other hand, while it must be cost effective, is not driven by having to be economically competitive.

Both ACTS and MILSTAR operate in the 30/20 GHz frequency band. The differences in the missions, however, of these two programs lead to differences in their functional requirements and therefore in their technologies. For example, individual terminal capacities are significantly different. ACTS, since it is intended to support the future growth in commercial telecommunications, would support high capacity terminals. The terminals would be able to carry up to 500 MBPS of traffic. MILSTAR terminals are designed to support 16 KBPS circuits. Consequently the technology in the two types of terminals will be significantly different. The total capacity of an operational satellite that could be developed using ACTS technology would accordingly be much greater than that of MILSTAR - 4-10 GBPS for an ACTS derived system contrasted with a capacity of less than 1 MBPS for MILSTAR. A corresponding difference between the two systems is in the switching and network control. ACTS technology will support 100,000 circuits controlled by an IF switch and another 60,000 circuits controlled by a baseband processor. MILSTAR will have its own baseband processor to control 15 highly secure circuits.

At the generic technology level, ACTS and MILSTAR do draw from the same technology base which was developed jointly by NASA and DOD.

There has been another recent development which has led to considerable discussion with respect to ACTS.

In December of 1983 the Hughes Communications Galaxy, Inc. filed with the Federal Communications Commission for authority to operate two Ka band communication satellites for supplying U.S. domestic services starting in 1988. Using the Ka band, signals are sent up to and are received from the

satellites respectively at 30 and 20 GHz frequencies. Current satellites in the U.S. use C band (6/4 GHz) and Ku band (14/12 GHz) frequencies. Japan is the only country currently operating Ka band satellites.

The Hughes satellite system will use all of the available Ka frequency bandwidth (which is five times that available at C and Ku bands). Its capacity will be about a factor of four times that of the largest satellite in service today. Two satellites are planned to be placed in orbit two degrees apart (one a backup for the other) to provide services over a ten year period. To a large degree, the Hughes proposed system is an extrapolation of current Frequency Division Multiple Access (FDMA) technology to Ka-band frequencies. The system will utilize current state-of-the-art integrated circuit technology for switching circuits on-board the satellite.

Much discussion has centered around the notion that the presence of the planned Hughes satellite negates the need for the NASA ACTS program. If the technology content were comparable and wide access to that technology were available as with ACTS then the obvious conclusion would be that the need for the ACTS flight program has been eliminated. However upon examination of the Hughes filing, it is evident that their proposed system is responsive to their perspective of what the market place will need in 1988 and not necessarily responsive to the technology needs of the 1990's. The Hughes filing is an important event and does represent a bold move by Hughes Galaxy Inc. It should not however be confused with the tenets of the ACTS program nor considered to be a substitute to attain the ACTS goals established by NASA in concert with the industry. There are significant differences in the technology planned for each system - as there should be. Hughes is responding to operational service needs while ACTS is aimed at advancing the state-of-technology to allow options to be exercised in the future - which will not be available if the program ends.

In summary, the ACTS technologies are different from those technologies required by the Hughes system and they require significantly greater advancements beyond the current state-of-the-art. The ACTS technologies are designed to provide very large capacity systems which utilize the frequency spectrum and orbital arc in a very efficient and conservative manner, provide a wide variety of services, minimize spacecraft weight and

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power to increase cost effectiveness, have a large degree of circuit routing flexibility and provide wide area coverage within the continental United States. These technologies will enable industry to build the advanced communications satellite of the 1990's.

VALUE OF NASA IN HIGH RISK R&D

When NASA re-established its satellite communications R&D activities in 1978, it was welcomed and applauded by many. The NASA program quickly became a force in steering the direction of technology development toward a goal which has resulted in strengthening the U.S. technological position in advanced satellite systems. NASA's continued presence in a meaningful way is essential in maintaining a strong technology base upon which the U.S. industry can, as they have in the past, build a capability unequaled in the world. The focus that NASA provides by spearheading the development of long term, high risk technology will allow maximum use of the industry's resources to maintain U.S. pre-eminence in this highly competitive field. The open access to the technology and the facilities which allow meaningful experimentation by system suppliers, service suppliers and users alike has no substitute. History tells us quite clearly that the availability of systems such as ACTS have stimulated a new industry, created new communication services and contributed to the economic well being of the nation.

We are now facing a decision reminiscent of that decision in 1973 which drastically reduced NASA R&D activities in satellite communications technology and removed flight experimentation from the NASA space program. We experienced a stagnation in high risk technology advancements and thereby encouraged entry into this U.S. dominated field by Europe and Japan. While we debated the wisdom of the NASA decision, a decade has passed.

While the NASA advanced communications R&D program slowed, Japanese and European efforts and funding accelerated. Exclusive of the Soviet Union, the world's first domsat prime contract outside of the U.S. was recently awarded to Aerospatiale of France for the ARABSAT system. The Japanese already have launched a communications satellite for tests in the Ku and Ka-bands. Although the first series of satellites in this program was bought from U.S. industry, several of the key components and subsystems were developed and provided by Japan. It is planned that

all subsequent models will be developed and produced in Japan. It is also noteworthy that the Japanese have become the leading supplier of INTELSAT earth stations and are likely to take the world market lead in the sale of TV sets designed specifically for direct-broadcast satellite reception. It is clear that U.S. industry no longer dominates the satellite communications market. It appears that both Japan and Europe have decided to forego major competition at C and Ku-band and to leapfrog technology by concentrating on the 30/20 GHz band.

The continued erosion of the U.S. position will be accelerated by the current decision. Ground testing does indeed contribute to technology development; however, the results will not have the impact of a flight system experiment. The planners and operators of future systems must make a judgment with regard to the technical readiness of any new concept and in particular those new concepts which dramatically change the way the business is to be conducted. As history has shown, private companies are not afraid to take risks when the extent of the risk is known. Ground testing of flight components and systems falls short of establishing confidence in the readiness of the technology for operational system implementation. The need for flight testing cannot be proved. As in many decisions, we must rely on lessons learned from history, the judgment of those who are knowledgeable and competent in the field and our own common sense. We must also consider the possible consequences of not following through with the ACTS flight experiment. It is not at all clear that we can afford to be wrong in this fast moving highly technical field. We must decide now whether the cost of ACTS is justified by the expected benefits--without the help of hindsight. Have all those who during the past five years closely followed the ACTS program development and continually supported the need for a flight experiment program been in error--or is the press of budgets within NASA going to cause history to be repeated?

By reopening the debate on this issue, we have already delayed the schedule by a minimum of six months. As a consequence, the funding required in FY 85 to continue the flight program initiative would probably be half the amount originally required. It is my understanding that the total program cost as established by NASA would not be materially affected by the slip except for inflation effects. In our current inflation environment the impact would be quite small (about $6 M over the total program). I think the difficult question that must be answered is "Can we afford not

to continue the ACTS initiative?

CONCLUDING REMARKS

I think there may be lurking in all this a larger question than simply one about foreign competition or near-term scarcity. It may be a question about NASA's legitimate role in space communications. From work done by our organization and from my own experience in the communications industry, I would conclude that there must always be a NASA presence in the area of technology development and risk-taking. We have a commendably diverse, competitive industrial complex in this country. That has many benefits, but it militates against long-range planning and high-cost experimentation. If we can continue to have a partnership of government and industry, specifically in this case, NASA and the aerospace/carrier industry, the U.S. can serve its own needs and serve the world. Any shift in this relationship could have dire consequences for our ability to compete in the communications technology market and to meet the growing needs of our own business and public service communities.

Mr. Chairman, this Subcommittee and its parent Committee have historically kept in mind the important benefits to the user community in participating in NASA's space communications programs. We look to your wisdom again as you consider the place of these programs in NASA's budget priorities.

Thank you, Mr. Chairman.

CORPORATE HEADQUARTERS

1660 L Street, N.W., Suite 907
Washington, D.C. 20036 • (202) 331-1154
ITT TELEX: 4991315

TECHNICAL CENTER

2480 West 26th Avenue, Suite 908
Denver, Colorado 80211 • (303) 458-7273
TWX: (PSSCTG DVR) 910-931-2686

MEMBERSHIP LIST

January 19, 1984

AFL-CIO

American Academy of Orthopaedic Surgeons

American Association of Community and Junior Colleges

American Association for Higher Education

American Association of School Administrators

American College of Physicians

American College of Radiology

American Dietetic Association

American Enterprise Institute

American Hospital Association

American Law Institute-American Bar Association
Committee on Continuing Professional Education

American Library Association

American Medical Association

American Red Cross

American Society of Clinical Pathologists

American Urological Association

Arizona State University - KAET

Association for Higher Education of North Texas (AHE)

Association of Hospital Television Networks

Association of Western Hospitals

Battelle Memorial Institute-Battelle Center for Improved Education

Burlington County College

California State University

California State University-Chico

California State University-Sacramento

Canadian Broadcasting Corporation

Catonsville Community College

Chamber of Commerce, U.S.A.

Clarkson College of Technology

Colleges of Mid-America

Committee on Institutional Cooperation

Community Television of Southern California - KCET-28

Credit Union National Association, Inc.

Cuyahoga Community College

Educational Testing Service

Fraunhofer - Gesellschaft (ISI)

Gallaudet College

Georgia Institute of Technology

Greater Cleveland Hospital Association

Greater Washington Educational Telecommunications Association

Hispanic Information & Telecommunications Network, Inc.

HSC-TV (Health Science Center TV Network)

Hocking Technical College

Illinois, State of - Department of Administrative Services

Indiana Higher Education Telecommunication Systems

Indiana University School of Medicine - Medical Education Resources Program

International University Consortium for Telecommunications in Teaching, Inc.

Iowa Public Television

Johnson County Community College

KEDDS/Link

Lakeshore Technical Institute

Learning Channel, The

March of Dimes

Maryland Center for Public Broadcasting

Medical College of Georgia

Mercy Hospital Medical Center, DesMoines, Iowa

Mississippi Authority for Educational Television

National Education Association

National Fire Protection Association

National Public Radio

Navajo Community College

New York Institute of Technology

Ohio Educational Broadcasting Network Commission

Ohio State University

Oklahoma State University

Oregon State Board of Higher Education

Practising Law Institute

Public Broadcasting Service

Public Communication Foundation for North Texas

Rocky Mountain Corporation for Public Broadcasting

San Diego County Department of Education

San Diego State University

South Carolina Educational Television Network

Southern Baptist Convention Radio & Television Commission

Southern Educational Communications Association

Stanford University

State Library of Ohio

TVOntario

Union Memorial Hospital

United Methodist Communications

United States Catholic Conference

University of California-Berkeley

University of California-Los Angeles

University of Central Florida

University of Colorado School of Medicine

University of Houston System

University of Nebraska-Lincoln

University of New Mexico/KNME-TV

University of North Carolina Television Network

University of Southern Mississippi

University of Texas Medical Branch

University of Utah-Media Services

Virgin Islands Public Television System

Virginia Department of Telecommunications

Virginia Polytechnic Institute & State University

Western Michigan University

West Virginia Educational Broadcasting Authority

West Virginia Research and Training Center

Wisconsin Educational Communications Board

COMMUNICATIONS SATELLITE OPERATIONAL NEEDS IN 1990's AND ROLES OF ACTS AND HAC Ka-BAND S/C

IMPORTANT NEW OPERATIONAL CAPABILITY NEEDED IN 1990's (AT Ku OR Ka BAND)*	ENABLING TECHNOLOGY (TO BE DEVELOPED BY ACTS)*	TECHNOLOGY APPLICABILITY TO Ku OR Ka BAND	FUNCTION (OR TECHNOLOGY) DONE BY HAC Ka-BAND SYSTEM
• CUSTOMER PREMISE LOW-COST TERMINALS CONNECTED ANYWHERE IN U.S.A.	• SCANNING S/C BEAMS • S/C BASE BAND PROCESSOR (DEMODULATION AND ROUTING)	YES	• NEITHER FUNCTION NOR TECHNOLOGY • LEAVES OUT 50% U.S.A. POPULATION • DOESN'T ADEQUATELY SATISFY MANY SERVICES (E.G., NATIONWIDE TELEPHONY)
• FLEXIBILITY TO ADJUST AMOUNT OF TRAFFIC BETWEEN ANY 2 POINTS (RATES FROM TELEPHONY TO TELECONFERENCING) — FIXED OR DEMAND ASSIGNMENT (DAMA)	• TDMA UP AS WELL AS DOWN (LIKE MOST CURRENT DOMSATS ARE DOING)	YES	• NO • USES SIMPLER, INFLEXIBLE FDMA UP • QUITE INEFFICENT IF TRAFFIC BETWEEN 2 POINTS IS NOT MULTIPLES OF T-1 (E.G., IF NEED 27 TELEPHONY CHANNELS, MAY NEED TO USE 2 T-1 OR 48 CHANNELS) • INFLEXIBLE FOR DAMA
• TRUNKING. COMPLETE INTER-CONNECT 20 OR MORE NARROW BEAMS	• SS-TDMA SWITCH WITH GROWTH TO LARGE SIZES	YES	• NO SS-TDMA SWITCH
• FLEXIBILITY TO ACCOMMODATE MANY THIN-ROUTE GROUND STATIONS (SAY 1000 OR MORE)	• ABOVE TECHNOLOGIES DO	YES	• PROBABLY NOT. COMPLETE INTER-CONNECTION AMONG 16 BEAM S LIMIT STATIONS TO 200 MAX (FOR PROPOSED 3000 T-1 CARRIERS)
• REDUCE OUTAGE DUE TO RAIN (Ka-OR Ku-BAND)	• POWER CONTROL IN S/C AND GROUND • ADAPTIVE S/C DECODING IN BASEBAND PROCESSOR	YES	• NONE OF THESE TECHNOLOGIES ARE DEVELOPED BY HAC S/C
• LARGE SPATIAL FREQUENCY RE-USE TO INCREASE USABLE SPECTRUM AT Ka-OR Ku-BAND	• MULTIPLE BEAM, LOW-SIDELOBE ANTENNA	YES	• NOT DONE SIGNIFICANTLY
• USE OF Ka-BAND	• DEVELOP RELIABLE Ka-BAND HARDWARE	NO (ONLY Ka-BAND)	• YES

*AS DESIGNATED BY CARRIER WORKING GROUP (AT&T, GTE, ITT, RCA AMERICOM, SBS, AMERICAN SATELLITE, ETC.)

2/2/84

NASA ACTS EXPERIMENTERS

Alternative Systems Lab

4953 Reedy Brook Ln.
Columbia, MD 21044

Applied Physics Lab/Johns Hopkins University

Johns Hopkins Rd.
Laurel, MD 20707

AZ Technology, Inc.

897 Independence Avenue, 3-F
Mt. View, CA 94043

COMSAT Labs.

Clarksburg, MD 20871

E-Systems, Inc.

10530 Rosehaven St., Suite 200
Fairfax, VA 22030

General Services Administration

Office of Information Resources Management
Washington, DC 20405

GTE Laboratories, Inc.

40 Sylvan Road
Waltham, MA 02254

Instituto de Pesquisas Espaciais (INPE)

CP 515
12200 Sao Jose dos Campos-SP
Brazil

Institute for Telecommunication Sciences

325 Broadway
Boulder, CO 80303

Scientific Atlanta

3845 Pleasantdale Road
Atlanta, GA 30340

ORI, Inc.
1400 Spring Street
Silver Spring, MD 20910

University of Miami

P. O. Box 248293
Coral Gables, FL 33124

The Ohio State University

Research Foundation
1314 Kinnear Road
Columbus, OH 43212

Partnership for Productivity

2441 18th Street, N.W.
Washington, DC 20009

Southern Illinois University

Department of Radio/TV
Carbondale, IL 62901

Jet Propulsion Laboratory

4800 Oak Grove Drive
Pasadena, CA 91109

RCA Astro-Electronics

P. O. Box 800
Princeton, NJ 08540

National Highway Traffic Safety Administration

400 7th Street, S.W.
Washington, DC 20590

TRW, Inc.

Electronic Systems Group
Space Communications Division
One Space Park
Redondo Beach, CA 90278

Motorola, Inc.

Government Electronics Group
8201 E. McDowell Road
P. O. Box 1417
Scottsdale, AZ 85252

National Bureau of Standards

325 Broadway
Boulder, CO 80303

Lockheed Palo Alto Research Laboratory

3251 Hanover Street
Palo Alto, CA 94304

NASA/Ames Research Center

Moffett Field, CA 94035

NASA/Lewis Research Center

Cleveland, OH 44135

Southern Educational Communications Association

P. O. Box 5966
Columbia, SC 29250

Tennesse State University

School of Engineering & Technology
3500 John A. Merritt Blvd.
Nashville, TN 37203

Science Applications, Inc.

1010 Woodman Drive
Dayton, OH 45432

Satellite Business Systems

8283 Greensboro Drive
McLean, VA 22102

LNR Communications

180 Marcus Blvd.
Hauppauge, NY 11788

Virginia Polytechnic Institute and State University

Blacksburg, VA 24061

2/84

INSTITUTIONS AND ORGANIZATIONS

INDICATING INTEREST IN EXPERIMENTING

on the

ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE

Communications Engineering Technology
Denver, CO

West Virginia Research and Training Center
Dunbar, WV

Chamber of Commerce of the United States
Washington, DC

Southern Educational Communications Association
Columbia, SC

Department of Education
Washington, DC

Native American Public Broadcasting Consortium
Lincoln, NE

The Network for the National University of the Air, Inc.
Williamsburg, VA

Agency for International Development
Washington, DC

Northern Colorado Educational Board
of Cooperative Services
Longmont, CA

American Red Cross
Washington, DC

Health Care Finance Administration
Baltimore, MD

New York Institute of Technology
Old Westbury, NY

Lockheed
Las Cruces, NM

Bank Administration Institute
Chicago, IL

Maryland Center for Public Broadcasting
Owings Mills, MD

Catholic Telecommunications Network of America
New York, NY

Commonwealth of Virginia
Richmond, VA

Association for Higher Education of North Texas
Richardson, TX

Committee on Institutional Cooperation
Evanston, IL

University of Illinois
Champaign, IL

City of Baltimore
Baltimore, MD

National Library of Medicine
Bethesda, MD

National Committee for International Education
Through Satellites
Philadelphia, PA

Portland Community College
Portland, OR

Federal Emergency Management Agency
Washington, DC

California State University
Sacramento, CA

San Diego State University
San Diego, CA

Grayson Gibbs and Associates
Belmont, CA

Indiana Higher Education Telecommunication System
Indianapolis, IN

National University Teleconference Network
Stillwater, OK

California State University-Chico
Chico, CA

Hispanic Information and Telecommunications Network, Inc.
New York, NY

University of Illinois at Urbana-Champaign
Urbana, IL

University of Texas at Austin
Austin, TX

Research Health Services
Kansas City, MO

Western Michigan University
Kalamazoo, MI

University of KY
Lexington, KY

Mr. VOLKMER. Thank you very much, Dr. Young.

I now recognize the gentleman from New Mexico for any questions he may have.

Mr. LUJAN. Thank you very much.

Gosh, I shouldn't have any questions, Dr. Young. You make a strong case for proceeding with the full-blown ACTS program, and if I'm not convinced by this time—but you do make a statement in closing that it's very close. You say, " * * * or is the press of budgets within NASA going to cause history to be repeated?"

I will invite you at some time in my office when folks from school boards come in and tell you, you know, that that should be the emphasis. Then follow the hospital people, and that's nothing compared to when the military come in, so there is a press of budgets and where that priority should be.

I really hate to be harping back on the same thing of whether this is development or research, whether the Hughes proposal is not just a first step to what industry would do, that once having accomplished that they would go into the wide range or the coverage that ACTS would give. Why would not industry go into that? As I see it, you know, it's the competition between AT&T and MCI, or what used to be, between St. Louis and Chicago and AT&T saying, "We provide coverage for the * * *," and it mentions all these little towns throughout the country. Why wouldn't that be the natural progression of things, after Hughes does their large market satellites?

Dr. YOUNG. Mr. Lujan, that's a very obvious question and I think there are two or three points that I would like to make from the perspective we've had since 1975.

First of all, as we see with the Japanese Ka-band program, the Japanese will now be designing a third generation, and yet they are still not testing what we would call truly advanced technology. They are saying, "We do want to operate at these frequencies," but they apparently feel that the risk of doing the switched beams and the onboard processor, even for them, is not yet at the point where they want to develop it. So there is a window here for the United States to get in ahead of the Japanese, and I think it would be safe to say Europe, probably the French.

There is no doubt that, given enough time, industry will experiment with and ultimately develop probably all of these technologies, but I think what we are talking about here is a timing problem. The threat of foreign competition is very real. The Post yesterday again had another story about computers, where we saw that Japan is now moving ahead of us in that field, which we knew in terms of small computers that was a possibility but now we're talking about an incursion into the large computer area, and it's demonstrable in satellite technology as well.

I think if NASA limits their testing to ground-based—which I have no doubt will not successfully cause the user community, the carrier community, and other manufacturers to immediately leap on board with the new technologies because they won't be successfully proven—it means that we've got about a 15- to 20-year lag. Maybe that means by the year 2000 we will have industry coming forward with some of this technology. I don't know. I think by then

the possibility of the United States even playing a very significant role in that market will be much, much less.

The second point that you raise or that is implied, I think, by your question, has to do with whether or not there is a need for this kind of R&D within NASA. The interesting thing is, if we look back at some of those previous programs I mentioned, there was a direct follow-on. The results of the CTS experiments—which went only for 2 years, which is exactly what ACTS has projected—have led to a direct broadcast satellite industry in this country, not yet up and running except with one company, but apparently going to be a thriving one in a few years. Would that have happened without CTS? Perhaps, but clearly not in the same timeframe, so there is an area where we have been able to make an additional commercial followthrough.

You also mentioned at the start of your question the obviousness of other priorities, when you talk to people who are concerned about education and hospitals. I must share with you a strong sense of *deja vu.* I sat I think in this chair—it might have been that chair—2 years ago when Mr. McGrath was on this subcommittee, and he said to me very much the same thing.

He said, "I understand the interest in this program and I understand communications satellites, but what do I do when elderly people come to me in my office and say, 'I don't have enough to eat,' or 'I need an improvement in the health care program.' How does communications help there?" And I told him the story, which is quite true, of being able to save lives with some of these satellites. We have done that in Alaska in the past programs. NASA is doing it now in the cooperative search and rescue program.

That relates to one of your other questions, which is, "Won't the marketplace be there and industry respond?" If you look at the Hughes filing right now, they are suggesting service to only 16 major markets, which are by and large the 16 top statistical metropolitan areas, which is a very sound business decision. That does not reach many of your constituents, Mr. Lujan, nor Mr. Winn's—and I worked in Mr. Winn's State for 2 years—nor Mr. Volkmer's, nor parts of Mr. Dymally's, nor Mr. MacKay's, nor Mr. Chandler's constituency.

The needs in rural America and the potential for increasing business there are very real. These are people who are willing to pay for service, but if they don't have it they can't pay for it, and the traditional role of industry has been to get in and make the dollars where they can. We're seeing some of the same thing develop in direct broadcast satellites, where it is clear the major metropolitan areas, despite all the rhetoric, will probably benefit first.

We are very concerned about the lack of ability to experiment with the small user, onpremise station. There is nothing in the Hughes filing to date which leads me to believe that would be a part of their system once it's up and running, nor of any other system which I have heard proposed, and we do serve a number of members including the American Hospital Association, which wants to be an experimenter on this program; West Virginia Training and Rehabilitation Center; the State of Virginia; and others who have already expressed an interest to experiment precisely to meet the needs of smaller population areas.

Mr. LUJAN. Well, if we weren't supporters before now, after that speech I guess everybody's ready to open up their pocketbooks, Dr. Young. [Laughter.]

Mr. LUJAN. Any chance of piggybacking on military experiments to do this sort of thing?

Dr. YOUNG. Mr. Lujan, I have a security clearance. I have not been briefed in about 2 years on the Milstar program, and what knowledge I have of that comes indirectly through NASA and other contractors who are working on it. I think the answer is not. The technology there, which is absolutely applicable to military needs, for example, is for fairly low data rates.

We're talking in ACTS about everything from full motion video or television to very high data rates that the Milstar program, with its satellite and corresponding Earth stations, would not be able to develop. They are also using what is called a spread spectrum technology for secure purposes, which is again absolutely appropriate—not what a normal user, a business user or a broadcast station, would need to use. So I think the chances there plus the problems of releasing that for civilian experimentation are slim to none.

Incidentally, in my conversations with everybody from the Secretary of Defense's office on down, there is strong support there for the ACTS program. There is a lot of interaction with NASA on this, a lot of sharing, formal and informal, classified and unclassified, but I think any opportunity to experiment with Milstar probably is not very real.

Mr. LUJAN. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you.

Now I recognize the gentleman from California, Mr. Dymally.

Mr. DYMALLY. Thank you, Mr. Chairman.

Dr. Young, you spent a great deal of time in your testimony talking about ACTS, so let me ask you the same question I asked Mr. Harter: Assuming NASA moves ahead with ACTS but limits it to a ground test program only, what tangible benefits would be gained or lost as compared to a flight program?

Dr. YOUNG. It's a key question right now, Mr. Dymally. I understand, although I wasn't here yesterday, that Dr. Edelson did briefly discuss the ground test program. We have seen no blueprint for that, no specific directives as to how that would be conducted, so I am at a little bit of a loss to respond directly but let me make some observations. As Mr. Harter has also pointed out, and our consortium feels even more strongly—we represent a user community, potential experimenters and ultimate users of this system—they gain virtually nothing by on the ground testing of a technology.

When a college or a group like the American Hospital Association wants to test this technology, what they mean by that is putting earth stations on premise and using the system for 6 months, a year, 2 years. That's the way in which they become users. To have simulated experiments between two NASA centers or whatever does them virtually no good at all. In the real world people make decisions based on their hands-on experience, and this has certainly been true of the user community in the past.

There are two other communities that I think suffer. One are the ground terminal manufacturers. We've talked with Scientific Atlanta, with Macom, with Harris, to mention just three of the large

system manufacturers. They want very much to build prototypes for this system, to see how well their prototypes work so they can take them back in the factory and make better ones, cheaper ones that work, in large quantities. Again, with a ground test only where you're not using a satellite, there is presumably no role for experiments by the terminal manufacturers.

And, as Mr. Harter has also noted, presumably the carriers suffer. There has been at NASA now for some 5 years a carrier working group, proposing its own experiments on the ACTS flight program, and to my knowledge none of them would have an opportunity to do very much of anything with ground tests only, so there are three significant groups who by and large dictate whether there will be a commercial follow-on that is successful, who would be shut out if there is a ground test program only.

Mr. DYMALLY. Since it's always possible for industry to develop its own advanced technology, what do you believe the proper role for NASA's Communications Research and Development program ought to be?

Dr. YOUNG. I think NASA always ought to be looking ahead 10 or 15 years as it has been in the past, to say where are commercial developers likely to move but, simultaneously, what are the technologies that are so high-risk and perhaps that are of public benefit, not necessarily just of market benefit, where no one else is moving? And I think it is incumbent upon NASA to also keep an eye, as they have, on developments in foreign countries. We don't have in this Government any single agency per se—I suppose the Department of Commerce, to some extent—that worries about foreign competition, but in the communications area, satellite communications, that agency must be NASA.

To date, they have been able to do a reasonably good job but I sat through a very alarming meeting yesterday afternoon of our Space Applications Board, where we heard testimony after testimony that in remote sensing we have already lost the ball game. There is no doubt about that— that the Germans are working very hard on the spectrometry; that the Japanese are ultimately going to be ahead of everybody else in the development of remote sensing radar; that the French, with their SPOT system, will be selling us data in the United States.

Now I am not an expert in that area, although I have sat on the Space Applications Board for 4 years, but it's very clear to me there that a slowing down, a lack of U.S. forcefulness in that area has caused this erosion, and I think exactly the same kind of thing can happen in the communications area.

Mr. DYMALLY. Isn't there a technical problem in timing of the satellite signals that can only be tested by a flight program?

Dr. YOUNG. We certainly think so. To test full motion video, to solve the problems of rain attenuation that invariably come up at these high frequencies, and—as you point out—to compensate for the slight loss, the quarter-second loss in the up-and-down links, has required to date a good bit of sophisticated testing with the previous Ku- and C-band satellites. These are all reasons, again, that make users hesitant to move ahead, and indeed probably manufacturers and carriers, without a full flight test program.

Mr. DYMALLY. Yesterday we pursued a line of questioning that had to do with whether commercial use of space, such as in materials processing, could be done as well or better in an unmanned mode than in a manned mode. I would like to have your views on the necessity of sending people on a space platform into space in order to make commercial use of space.

Dr. YOUNG. Again, Mr. Dymally, my area of expertise is communications and not materials processing. By virtue of my service on the SAB, I have been privileged to hear a number of reports on experiments on the shuttle, and I did participate in the space station study that Mr. Harter referred to.

A couple of observations: I think there is no doubt there are certain things we can do in space with materials processing that cannot be done on the ground, due to the difference in gravity and so on. Whether or not we need a fully staffed and manned platform at all times I think is open to question.

One thing that does trouble me about these discussions, however, is not so much the manned/unmanned aspect. We talk about NASA's proper role, and there seems to be a consensus that it is in developing high risk R&D, whether it is in materials processing or remote sensing or communications. To my understanding, the type of space station which is being proposed is all with existing technology. While the research that would go on on the space station in materials processing and other areas might be very advanced, the literal components of the space station are pieces of hardware and technologies which are with us today.

Now there, it seems to me, is an area where we can ask for industry participation. If we need a space station to do the advanced experiments, as I believe we certainly do in materials processing, although not so much in communications at this time, why not have that space station provided commercially and allow NASA and perhaps other Government agencies to participate by funding the experiments? That seems to me an issue that, in my cursory reading of discussions about the space station—and I have had none on the official level—is an obvious question that no one has asked.

Mr. DYMALLY. The committee is about to introduce legislation to lay out guidelines for the commercialization of the Landsat program. I believe the committee's conclusion is that the greatest potential for commercialization is in the value-added area. Could we hear your views on that?

Dr. YOUNG. Again, we have a separate problem in communications. Once the communication is transmitted and received, we don't generally have to add value other than a minor decoding. In remote sensing, as I understand it, all of the value is indeed in value-added communications. I think that there is no question that's where the money is to be made, but my understanding is that there are serious issues about privacy, international use of data, and other policy questions—for example, who will pay?

As just a layperson in this area, I find it inconceivable that we might end up paying more from Government agencies like the Department of Agriculture, to pay a private supplier to decode, reenhance the information, and sell it back to us. In other words we would in fact be, with tax dollars, subsidizing a system that is even

more expensive than the present system we now use, where Landsat is run by NOAA through the Department of Commerce. But I would prefer not to be quoted as an expert on that area, because I am not.

Mr. DYMALLY. Mr. Chairman, one final question:

Are those satellites which were not successful members of your consortium?

Dr. YOUNG. Mr. Dymally, fortunately we're in a position where we lease time on virtually all the domestic satellites that are operating at this time, and we do lease time from both Western Union and RCA, AT&T, on their existing satellites. We were in discussion with Western Union about a full transponder on Westar 6, which was the first one that was lost in space, so there will be a negative impact for us probably in the next 6 to 8 months.

We have found it extremely difficult to find available time, incidentally, which bears on your earlier question about scarcity, so there is clearly going to be an impact on the user community. We too are concerned about the orbit crowding, about the lack of available transponders, and about what this means in the next 5 to 10 years.

Mr. DYMALLY. Which leads to my final subquestion: Do you think there has been a loss of confidence as a result of the two unsuccessful launches, in your consortium?

Dr. YOUNG. I have talked informally with some of our larger members who are using satellite communications quite regularly, and up until this week we were usually able to say to them, "Nothing goes wrong with the satellites," which by the way was generally true. Incidentally, I think it's interesting to note that when NASA had complete responsibility for launches, meaning all of the intermediate stages and rockets, there was a 99-percent reliability on the launches. I don't know if there is a lesson there or not but yes, there is a concern in the user community and, by the way, certainly in the insurance community which has yet to make a profit in this area. [Laughter.]

Mr. DYMALLY. It seems like that's a good plug to increase NASA's budget.

Thank you very much, Mr. Chairman.

Mr. VOLKMER. The gentleman from Washington.

Mr. CHANDLER. Well, just one question, Mr. Chairman, and that concerns the ACTS program: How would the beam-switching capability of ACTS interact with the ground-based fiber optics systems being developed?

Dr. YOUNG. We see fiber optics as a logical extension, Mr. Chandler, of what we call the last mile problem, particularly with today's satellites where you deliver a signal down to a fairly large Earth station, and often the end user or users are dispersed from that, as in a broadcast situation. With the TDMA up and down and the switched beams on ACTS, we hope that the switched beams will be able to dwell for short times on user premises, but it may very well be—take a situation in a community where the Earth station is located at a school district—that that school district can have access to a beam for as little as a few minutes a day for message switching, but then those messages need to travel further out

on the district to other schools or other district offices, and that can be accomplished by fiber optic technology.

I have never seen those two technologies in competition for domestic purposes. They may turn out to be across the Atlantic, competitive or backup to each other, but fiber optics are a terrific extension of technology for that final mile problem when we deal with satellites.

Mr. CHANDLER. Thank you, Mr. Chairman.

Mr. VOLKMER. I would like to say, as one who firmly believes in the NASA shuttle program, that it isn't the shuttle program that lost us the Palapa B and the Westar, it's the——

Dr. YOUNG. That's right.

Mr. VOLKMER [continuing]. Or it appears at this time to have been the PAM module that didn't operate properly.

Dr. YOUNG. Exactly, Mr. Volkmer. The shuttle did its job. They deliver, as they say, on schedule.

Mr. VOLKMER. And another thing, I think it's too early to say at this time, to use the word "lost" as far as those satellites are concerned, because there are some of us that are looking at the possibility of where they are right now and being able in the future, with what just happened with McCandless and Stewart, to be able to bring them back some day in the future and send them up again. It appears that the satellites themselves are not in any trouble themselves.

Dr. YOUNG. I don't know that we know that. We have never recovered a communications satellite from space.

Mr. VOLKMER. I know.

Dr. YOUNG. We share your hope, for sure.

Mr. VOLKMER. OK. The other thing that I would like to get into just a little bit is, on page 2—it may take a little while to develop this, but we'll see where we're going—you say "The FCC is currently faced with the problem for the first time of having more applications for new satellite systems than can be accommodated in the remaining orbital arc at both C-band and Ku-band frequencies."

I don't have any information right now, offhand, on the Ku band. I do have on the C band, and I have "Satellite Weekly" here who on January 23, 1984, state that there is a glut in inactive transponders available. As I read this, at that time there was an increase of plus 48 and total inactive transponders of 143 in the C band.

Dr. YOUNG. Would you like me to comment on the apparent discrepancy between what I said and what——

Mr. VOLKMER. Yes; I want you to comment on why we are having so many filings for new satellites that will have more excess transponders, and why we're not utilizing the present transponders that are inactive.

Dr. YOUNG. A couple of things, Mr. Volkmer: First of all, that report was generated by a piece of research that the Federal Communications does about every 6 months. They select a given day and they look at all the existing satellites and see whether there is any activity on the transponders. Part of the problem is, no matter what time of day you do that—and to the best of my knowledge they do not do it continuously over a 24-hour period—given transponders are going to be vacant. There is a reason for that.

Many of the transponders that are used, for example, to feed cable systems and broadcast stations, have their heaviest traffic during the prime time hours in the evening, so if NASA does a sighting, say, from noon to 5, those transponders may be unused at that time. Conversely, there are other transponders, particularly the ones we generally use—because our business tends to be roughly the business day—for video teleconferencing, will be active from 9 in the morning until 4 or 5 in the afternoon and then idle in the evening.

Another reason for some of the idle transponders happens to be that right now most of the ground stations are looking at a minority of those satellites, and I say "right now" because that's changing very rapidly with the technology. There are 4,500 cable systems in this country, about 80 percent of which are taking programs from satellites, and there is a very active campaign for cable programers to get on. Those cable systems mostly look at two or three satellites, but that's changing.

We have a technology now called multibeam antennas, which means that instead of putting one Earth station out looking at one satellite and another one next to it and so on, you can access all the domestic satellites simultaneously. As the cablecasters and the broadcasters and the business users begin to buy into the multibeam technology, we'll be able to spread the programing out more and there will be less severe competition, as there is right now on a satellite like Satcom 3-R, where you simply can't get time anytime during the day, 24 hours a day, on any transponder.

So the fact is that there is a tremendous push for time on certain of those satellites but because we don't have the Earth stations accessing all of the others, there appears to be a glut, although some of that again is illusory.

The other thing that has happened is, some of the big networks will buy up or lease transponders on a number of the satellites and not lease them out to other users, such as our consortium, but they keep them for backhauling of events—perfectly legitimate. We don't mind that, but it means that if CBS or ABC have control of 10 or 12 transponders, at any given time they may only be using one or two, but during the Olympics or during the campaigns they may fill all of them with remote signal return to New York, and they're willing to pay the freight. So if you ask how many of those are leased or how many are paid for, the answer, except for those that are not well—some of the transponders don't work properly—or are being reserved by the carriers for their own maintenance purposes, virtually all of those are already leased out.

The other thing, as you know, is that last fall when the Commission opened up again to future filings, all available Ku band space was taken and we had the first filings for Ka band, which came as a surpise even to us. Naturally that assumes some optimism on the part of the companies filing, but I think it's quite true that even today, notwithstanding the actual traffic at any given time, virtually all those transponders are leased and paid for. That's why we see a problem.

Mr. VOLKMER. Now we have seen the continued growth in the communications field and the need for additional satellites. Do you anticipate at any time in the future, with the use of the Ka band

as well as the C and the Ku, that there will be a leveling off—let's put it that way—in the demand for the use of those?

Dr. YOUNG. I think that there will not be in the next 20 years. Fiber optics, as Mr. Chandler has mentioned, is a good alternative technology for some purposes. It doesn't do a very good job of wide-area distribution—coming up from a single source and going down to many sources. It's best on a point-to-point application.

When we look back at the estimates that we've all made—Government, private users—about satellite communications, the real demand has in each case exceeded the estimates by some percentage, so we've been a little under in these areas. The prospects we see are for the most tremendous growth of the need for satellites in the data field.

Voice and data will be the fastest-growing services. Video may be the most apparent to all of us, particularly as consumers, but what we are probably going to have in the year 2000 and the next century is every business routinely interconnecting with its own branches, its own customers, even its own employees, using technologies like those being developed in ACTS which are particularly amenable to small user terminals, in combination with such things as fiber optics.

So I would say that in my view, and knowing something about the entertainment industry where I did spend some time as a broadcaster, I don't see the demand leveling off for at least another 20 years. Now catastrophic events, of course, with the economy or the world could change that, but the whole world seems to be moving more and more toward greater uses of communications, and certainly satellites are going to play a role in that in our view.

Mr. VOLKMER. What is the future that you can tell us about, if at all possible, in the user community for the low-cost, small, Earth-type terminals that I could have in my car or my home or that type of thing? You mentioned, I believe, in your statement about the Japanese and direct-view television through the use of the Ka band.

Dr. YOUNG. Yes. Well, both in dbs and, we think, Ka band the Japanese are looking very seriously at that market. The prototype Ka-band terminals that would be needed for an ACTS type of program would start—it's very hard to estimate this yet—but informal discussions, we're probably talking about a 2-year experiment requiring $70,000 to $100,000. That's a complete up-and-down link, so you can transmit as well as receive.

If we look back at the history of C band, which is what we're most familiar with, and you compare the scaling down of costs there where we started with transmitters well over $100,000, with terminals well over $100,000, and now you can pick up a C band receive-only for under $3,000, we would expect an appreciable order of coming down of the price of the K-band terminals. My guess is by the time they are on the market in the 1990's, $30,000 to $40,000 for a nonredundant up-and-down link—again, the kind you would use in a small business, a school, a hospital, for electronic mail, data, voice, slow-motion video—is a reasonable cost.

Right now, to uplink with the current satellites, with a Ku band or C, still requires a piece of equipment that has a cost on the order of $250,000 to $300,000, so if we can bring that down by an

order of magnitude with this advanced technology, that is a significant saving.

You asked about your car, by the way. I have to add that the mobile program which NASA hopes to engage in with Canada and the other industry players there, now we're talking about something on the order of $200 for an antenna that would either be a mesh antenna on the roof or a whip antenna just like the one you already have, and that's truly a remarkable technology.

Mr. VOLKMER. Now to get to the ACTS and the flight test, and there is no question in my mind that you would prefer to have the flight test——

Dr. YOUNG. That's correct.

Mr. VOLKMER [continuing]. And the reasoning why, but I do note that you say here—and this is something that undoubtedly we will have to go back and go over again with NASA, because on page 8, the one sentence: "The need for flight testing cannot be proved."

Dr. YOUNG. Right.

Mr. VOLKMER. In other words, it's a question of desirability.

Dr. YOUNG. Certainly. Look, you're going to get, you know, any answer that—depending on who you talk to—someone wants to give you, and it becomes something of a judgment call. I think that the greatest evidence that the flight program would be required would simply be a dialog with the potential carriers and Earth-station manufacturers and users.

Mr. VOLKMER. That suggests another question, and that is, is there or is there not a technical problem in timing of the satellite signals that can only be tested by a flight program?

Dr. YOUNG. Yes, there is, and I think Mr. Dymally when he was here was getting at this as well. We do have with satellite technology about a quarter-second delay to complete an up-and-down circuit, and this is the kind of thing where we do need to build in compensation for that, forward-error correcting, on board the satellite as has been suggested in the ACTS program. Here again is where the user community, which is a lay community for the most part, simply is uneasy about taking the word of a technical report that this whole thing is going to work and making ultimately millions of dollars of investment in an unproven system. They want the hands-on experience.

Mr. VOLKMER. In other words, to get me in a little bit better focus on the user system which you represent, when someone—whether they are instigating it or the satellite owner is instigating it, which way the push or pull is coming from as to demand—they want to make sure that the system works before they invest any money, just like anything else.

Dr. YOUNG. That's exactly right. We did a lot of experimentation with ATS and CTS with the VA hospitals, for example, and they simply would not have done anything in the satellite field if we hadn't been able to put those terminals on their roofs and handhold them through 2 years of experiments because otherwise, for very good reasons of cost effectiveness, they were inherently conservative about adapting any new technology.

Mr. VOLKMER. OK.

Does anyone have any further questions?

Mr. LUJAN. Yes. Getting back to either ground testing or in-flight testing, the budget was reduced from what, from $90-some million——

Dr. YOUNG. $92 million to $5 million, as I understand it.

Mr. LUJAN. Is that amount actually required? Do you think we could do with less? Give me an overall, not just the 1-year funding, because this certainly is the best short-term recovery as far as the expense is concerned. All of our other things that will bring back money are more long-term than that. What I'm getting at is, do you think we need to go back to the full $92 million, and then what beyond that? Give me your thoughts on that.

Dr. YOUNG. Would be needed? All right. I was afraid you were going to ask me what the ground test system would cost, and since I don't think NASA has defined it and I don't think they know, I don't either, but I prefer to answer the other question.

The budget runout, Mr. Lujan, if the program had proceeded on schedule was—and I know your staff have this, but let me just review it for the subcommittee—it was $92 million in 1985, $98.5 in 1986, $90.5 in 1987, and then a very fast scaledown—$37 in 1988, which would have been the year of the launch, $6 million in 1989, and $5 million the following year or just a runout to close the files and hand over the satellite to a consortium of users or industry, which by the way was the plan, so there could be some further use.

Mr. LUJAN. Some $300 million?

Dr. YOUNG. Yes, some $354 million, beginning with the start of the program, with the $20 million and the $5 million that have already been appropriated.

Mr. LUJAN. Yes.

Dr. YOUNG. Now my understanding is that even if there were a delay now of 6 months to a year, that would be acceptable, that we're still reasonably well on course. Contracts could be signed. The experiments could begin to be built, so I guess if we're talking about 1985 dollars or appropriations we're saying roughly half of the originally requested amount, or some $45 to $46 million, would keep the program on course, recognizing we would have to pick that up in the out years. We would be essentially on a half-year delay cycle.

I think quite candidly that equally important, if this committee or its counterpart committee in the Senate wants to do that, will be to get directive language into your bill and ultimately into the appropriations bill to let NASA understand that this is a priority, because what troubles us particularly is the flip-flopping of the program. Two years ago it wasn't going to go in, and then it did, and now it sort of is, and maybe next year it won't. Of course, we don't even have any guarantee of what industry is going to do. It's perfectly proper for them to take another look at this area and say, "Well, the 16 markets we looked at aren't developing. Cancel our program." And here is NASA left with a shell of what was a good developmental program.

Mr. LUJAN. Thank you, Mr. Chairman.

Mr. VOLKMER. Well, thank you, Dr. Young. I appreciate your being here this morning. You have been very informative.

Our next witness will be Dr. Alan Lovelace, vice president for public policy, American Institute for Aeronautics and Astronautics.

I want to welcome you again, Dr. Lovelace, to the subcommittee. Your statement will be made a part of the record in full. It will appear in the record in full. You may either summarize or review the statement in full, however you so desire.

I understand you are accompanied also by Dr. David Rohrbaugh, Space Systems Technical Committee.

STATEMENT OF DR. ALAN M. LOVELACE, VICE PRESIDENT FOR PUBLIC POLICY, AMERICAN INSTITUTE FOR AERONAUTICS AND ASTRONAUTICS

Dr. LOVELACE. That's correct, Mr. Chairman, and we appreciate the opportunity to appear before your committee and to present on behalf of AIAA our views on the NASA space budget that is before this Congress for its disposition.

Let me just very quickly remind the committee that the AIAA is a nonprofit, technical professional society with over 34,000 members, principally engineers, scientists, and students, who are engaged in every sector of the aerospace profession from industry to Government to the universities. The institute's professional membership is divided into 68 sections around the country, and to further scientific and technical advancement we have 51 technical committees covering every aspect of the aerospace profession.

Our testimony today does not necessarily represent a consensus of our membership, any more than one administration is a perfect representation of the will of all of the people. Our testimony represents the expertise of a select group of our members who are given this responsibility by me in my capacity as vice president for public policy.

Seated here with me today is Dr. David Rohrbaugh, who is vice chairman of the AIAA Space Systems Technical Committee which, in consultation with other technical committees, has prepared our testimony and to which I have given my approval. I would like to ask him to summarize the high points of that assessment.

STATEMENT OF DR. DAVID J. ROHRBAUGH, VICE CHAIRMAN, SPACE SYSTEMS TECHNICAL COMMITTEE, AMERICAN INSTITUTE FOR AERONAUTICS AND ASTRONAUTICS

Dr. ROHRBAUGH. Thank you, Dr. Lovelace.

Mr. Chairman, I will summarize our comments. We welcome the opportunity to come before you again this year to offer an outside perspective on the NASA space research and development budget. This year we have organized our remarks into the areas of space science and applications, technology utilization, space transportation, and space research and technology.

In the area of space science and applications, we are gratified that NASA is proposing a new start for the Mars geoscience/climatology orbiter, the first in a new class of low-cost planetary observers. We are also encouraged with the new start of the upper atmospheric research satellite which we feel is indeed timely.

For near-Earth studies, the shuttle potentially offers a variety of opportunities for space science. The successful spacelab mission last year clearly demonstrated that we are now well on our way toward realizing that potential.

However, in our testimony to you last year we expressed concern over the slow pace of shuttle science development. We must reiterate our concern this year. Of 29 U.S. experiments selected from the 1978 Announcement of Opportunity, only a handful have been funded; none have flown. Attention needs to be focused on smaller payloads not requiring full pallet integration, including getaway specials and free-flyers.

In our testimony last year we underscored the importance of a strong basic research program. Unfortunately, the planetary exploration research and analysis budget is down 13 percent from last year, and the physics and astronomy R&A is down 5 percent after inflation.

In the area of space and terrestrial applications, we continue to support the strategy of transferring mature capabilities to other civil or commercial operators and users as appropriate. However, the evolution of the U.S. space materials processing program has been slow. NASA should continue to support materials research at an increased level of support, and should plan for materials research as a part of the space station capability and establish reasonable policies for the use of that facility by industry.

In considering the importance of NASA's advanced communications technology satellite [ACTS], the AIAA is on record in prior congressional testimony in support of the ACTS program. As private sector initiatives are developed which adequately cover the aspects of the ACTS technologies, a reexamination of the program content may be required. Certainly continued U.S. leadership in the field of space communications, the vanguard of space commercialization, is consistent with both administration and congressional guidance.

Before leaving the area of space applications, there is one more point which must be noted. We have cited balance as a criterion for an effective space program. We therefore applaud the balance NASA has struck between the science and application programs and other flight activities. We concur that this balance should be maintained in the future.

I would now like to turn to the area of space transportation. During the past year the shuttle has moved closer to a true operational capability. Obtaining such a capability must continue to be NASA's highest priority. We have consistently held an opinion that an investment which retains the option for an additional orbiter would be wise. The capability to produce orbiters is a national asset that has taken 12 years to develop. It is essential that the Government, with the help of the shuttle industrial team, define an orbiter production and operational support plan for a 15- to 20-year program. Any system that is committed to supporting long-range national objectives, as is the space shuttle, must have the Government's commitment.

We are very pleased that the President has directed NASA to proceed with a manned space station. There can be no more fitting tribute to Americans vision than that the beginning of a permanent presence of U.S. citizens in space in 1992 will be the 500th anniversary of Columbus' historic voyage.

A balanced program for our national space operations capability should also include planning for advanced launch vehicles and or-

bital maneuvering and transfer capabilities. Effective operations in low Earth orbit will require an orbital maneuvering vehicle. The continued funding of this program is essential to provide a vital link in our transportation system. Similarly, our support for the orbit transfer vehicle development program remains strong.

Overall, we believe the research and technology program is being well supported.

In conclusion, Mr. Chairman, we feel that NASA's space program is relatively healthy and well-balanced, but we find no long-range plan, no vision by which today's activities can be measured. Without such long-range perspective, the adequacy of current plans defies assessment. With it, new opportunities become clear.

We feel that a national long-range space program plan could be dynamic, living strategy, without violating our call for stable commitments. Let us join together to build and maintain a consensus regarding our Nation's future civil space activities. With such a vision we shall all advance.

Mr. Chairman, that concludes our prepared remarks. We would, of course, be happy to answer questions.

[The prepared statement of Dr. Lovelace and Dr. Rohrbaugh follow:]

AMERICAN
INSTITUTE OF
AERONAUTICS AND
ASTRONAUTICS

1010 16th STREET N.W.
WASHINGTON, D.C. 20036
202/785-0293

Statement to

Subcommittee on Space Science and Applications
Committee on Science and Technology
United States House of Representatives

by

Dr. Alan M. Lovelace
Vice President, Public Policy

and

Dr. David J. Rohrbaugh
Space Systems Technical Committee

February 8, 1984

American Institute of Aeronautics and Astronautics

Introduction,

Dr. Alan M. Lovelace

The AIAA is a non-profit technical professional society with over 34,000 members who are engineers, scientists and students engaged in every sector of the aerospace profession from industry to government to the universities.

The Institute's professional membership is divided into 68 sections around the country. To further scientific and technical advancement, we have 51 technical committees covering every aspect of the aerospace profession. Our testimony today does not necessarily represent a consensus of our membership, any more than one administration is a perfect representation of the will of all the people. Our testimony represents the expertise of a select group of our members who were given this responsibility by me in my capacity as Vice President for Public Policy. Seated with me here today is Mr. David J. Rohrbaugh, Vice-Chairman of the AIAA Space Systems Technical Committee, which, in consultation with other technical committees, has prepared our testimony, to which I have given my approval.

Statement by,

Mr. David J. Rohrbaugh

Thank you, Dr. Lovelace.

Mr. Chairman:

We welcome the opportunity to come before you again this year to offer an outside perspective on the NASA space research and development budget.

As President Reagan clearly emphasized in his State-of-the-Union Address, there are few ways to better invest in the nation's future than in the civil space program. We share the President's perspective. Government support of civil space activities contributes directly to the maintenance of national vitality and security.

Mr. Chairman, we noted here last year our view that 1983 was to be a watershed year for the civil space program. With the inauguration of operational shuttle activities, including the Tracking and Data Relay Satellite System (TDRSS), the Inertial Upper Stage, Spacelab, and related civil, commercial, military and scientific activities, we have begun a new chapter of our national space program. We have recently seen a major redirection in our nation's planetary exploration program. The strong need for government and private sector cooperation in fostering the proper development and execution of space applica-

tions is now well accepted. During 1984, we anticipate major progress in each of these areas. The leadership of this Committee in promoting these and other key steps is to be commended. In Fiscal Year 1985, we must continue this trend to reinvigorate the U.S. civil space program.

Once again, the past year has also been one of intense activity for the AIAA. Through various publications, symposia, working groups and meetings, we have continued to refine our insight into current and future NASA activities. Where appropriate, I shall point out these relevant AIAA activities in commenting on specific program initiatives. I also want to note that many key issues regarding NASA's program have been discussed at length during the past year in the pages of our magazine, Aerospace America (formerly Astronautics and Aeronautics, or A/A). Where appropriate, I will also note these references as supporting material.

We are especially pleased to have been invited last May by the Congressional Space Caucus to share our view of the next twenty years of the civil space program. In the process of preparing and presenting this prospectus, we crystalized a unique perspective of the possibilities offered to our nation by civil space activities.

This perspective was based in part on the AIAA view of U.S. space policy, which Dr. Rosen reviewed for you last year. For the record, we recommended that the National Aeronautics and Space Administration should:

- Make a firm commitment to a national space program plan, in its area of responsibility,
- Continue scientific exploration of the moon, comets, asteroids, the planets, the Earth, the Sun, the stars and the Universe,

- Continue and intensify development and, when possible, promote commercialization of communications, earth-observation, space materials, processing and manufacturing capabilities,
- Continue and initiate vigorous programs in the enabling technologies which are essential to all space activities,
- Continue and expand the evolutionary development and effective operation of a space transportation system, and
- Establish a program commitment to an evolutionary manned space capability in low earth orbit.

This last point is a step the AIAA has consistently supported, and of course, we were pleased to hear the President's January 25 directive to NASA to develop a permanently manned space station.

However, we still strongly feel the need for a national space program plan, complete with schedule milestones. Although we have taken no position as to the specifics of such a plan (other than those already mentioned), we have repeatedly emphasized the need for long-term commitments to add needed stability to our efforts. As we have consistently noted, stability, itself, will go far toward insuring the vitality of U.S. accomplishments in space. I will return to this point later.

These, then, are the key elements for ensuring an adequate civil space program: balance, stability and perspective. They are the criteria by which we have measured the proposed FY 85 NASA budget submittal.

This year we have organized our remarks into the areas of space science and applications, technology utilization, space

transportation, and space research and technology. And, of course, we shall comment on the President's Space Station initiative as appropriate. We are pleased to see that, in each of these areas, the proposed program is now consistent with avowed U.S. space policy. Moreover, we believe that this year, more than before, the proposed budget comes much closer to meeting the overall objective to which we in the AIAA have concurred: maintenance of leadership in space. We are now well on our way to a balanced, adequate civil space program. That is not to say there are no shortfalls in the budget - we shall identify the most distressing. But, overall, the proposed budget is a step in the right direction.

The space science budget proposed by NASA for FY 85 shows a 15% increase in real dollars over FY 84.

We are encouraged by the new start for the Mars Geoscience/ Climatology Orbiter and continued support for Space Telescope, Venus Radar Mapper, and other projects already under development. However, the Administration is still not heeding the need for basic research support, despite the recommendations of all recent science advisory committees and the clear wishes of Congress.

Under the planetary exploration program, we have begun to answer many fundamental questions of our beginning by exploring the planets and observing the formation of other solar systems (A/A, Jan 83). The Galileo mission is proceeding towards its Shuttle-Centaur launch in 1986. It will be the first planetary mission launch in nine years and promises to open a new vista in our understanding of the giant planets and their satellites. The science community also awaits the 1988 launch of the Venus Radar Mapper which will give us our first high-resolution map of this cloud-shrouded planet and contribute new insights into the geology of the terrestrial planets, including the earth.

We are gratified that NASA is proposing a new start for the Mars Geoscience/Climatology Orbiter (MGCO), the first in a new class of low-cost planetary observers recommended by the Solar System Exploration Committee (SSEC). MGCO will be targeted for launch in 1990 and will send back data on the geology and climate of Mars for a complete Martian year. However, the success and economy of the planetary observers depends on a continuing program, similar to the successful Explorer series, with sufficiently frequent new starts for modest missions that cost-sharing of support personnel and hardware can be realized and which will involve a larger portion of the science community than any one mission alone. The SSEC recommended funding the planetary observers as a line item to insure this continuity. We endorse their recommendation, and we hope that in future years NASA will adopt this approach.

We have also endorsed their proposed exploration of primitive bodies such as comets and asteroids. Disregard of these scientifically rewarding activities is not in our best interest. Finally, we have long recommended a renewed program of lunar science and exploration. Fifteen years after the first manned lunar landing, we should now turn our sights again to our nearest planetary neighbor. (A/A, Nov 83)

In the physics and astronomy program, we are pleased that the Hubble Space Telescope is receiving adequate funding to be ready for launch in 1986. Free from the distortions of the earth's atmosphere, Space Telescope will bring exciting new discoveries in many areas of astronomy. To take full advantage of this long-term national facility, however, will require continuing funding for instrumentation as well as research support for the scientists who will use it. We also remind the committee that the start of the Solar Optical Telescope, an important facility for increasing our understanding of the Sun, still waits in line behind Space Telescope.

The Gamma Ray Observatory as well as the Extreme Ultraviolet Explorer and Cosmic Background Explorer are proceeding, with launches toward the end of the decade. Each of these satellites will make important contributions to our knowledge of the universe in a region of the electromagnetic spectrum inaccessible with conventional telescopes. The IRAS[1] satellite launched in January 1983 was a complete success and has already led to exciting new discoveries. We congratulate NASA on a mission well done. Processing and analysis of the infrared sky survey will continue into FY 85.

Looking further into the future, it is gratifying to see planning for future missions now proceeding apace. The new start for the Upper Atmosphere Research Satellite (UARS) is indeed timely, as we noted last year. Instrumentation for this important mission has been under development for several years, and now is the time to begin mission and spacecraft programs.

Other advanced planning activities, especially for TOPEX[2] (A/A, Nov 83), AXAF[3], SIRTF[4], and OPEN[5] promise a well balanced program of space science in the future. However, funds for a Phase B study of the Shuttle Infrared Telescope Facility (SIRTF) are not included in the FY 85 budget. SIRTF is designed to be a follow-on to the IRAS mission, making detailed observations of objects discovered by the IRAS sky survey. Proposals for instrumentation have already been solicited, and the strong response indicates wide support in the scientific community. A long-duration free-flyer now seems to be more appropriate than a shuttle pallet mounting. We hope that NASA will revive this project and move to a Phase B study.

We especially want to encourage NASA to pursue the OPEN program (Origin of Plasmas in the Earth's Neighborhood). This set of missions would contribute significantly to our scientific

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1 Infrared Astronomical Satellite
2 Ocean Topography Experiment
3 Advanced X-Ray Astrophysics Facility
4 Shuttle Infrared Telescope Facility
5 Origin of Plasmas in the Earth's Neighborhood

understanding, and be an excellent example of international scientific cooperation.

For near-earth studies, the Shuttle potentially offers a variety of opportunities for space science. The successful Spacelab I mission last year clearly demonstrated that we are now well on our way toward realizing that potential. All participants are to be congratulated.

However, planning and execution of that mission was exceedingly complex. Moreover, in our testimony to you last year, we expressed concern over the slow pace of shuttle science development. We must reiterate our concern this year. Of 29 U.S. experiments selected from the 1978 Announcement of Opportunity, only a handful have been funded; none have flown. The first flight, the Astro payload of three ultraviolet experiments, is now scheduled for 1986. A major problem is the cost and complexity of payload integration. While some improvement has come with experience, and paperwork has been streamlined somewhat, more needs to be done. If we cannot effectively integrate science payloads onto the Shuttle, how can we hope to efficiently use future platforms or stations?

Attention needs to be focused on smaller payloads, not requiring full pallet integration, including get-away specials, and free flyers. For many space science and earth science observations from earth orbit--looking outward to study the solar system and the galaxy; looking downward to study the earth's resources; and measuring <u>in situ</u> the properties of the earth's atmosphere--a free-flyer carried into orbit by the Shuttle is more appropriate than an experiment mounted in the Shuttle bay. A free-flyer (1) avoids contamination from the Shuttle environment, (2) eliminates the need for particular Shuttle orientations and extremely stable Shuttle pointing capability, (3) reduces

cost by avoiding pallet integration, and (4) allows long-duration observations if the free-flyer is retrieved on a later Shuttle flight. At present, there is no single point of contact in NASA management, or in the NASA budget, to promote and coordinate smaller payloads, stimulate new ideas and encourage wider use of potential opportunities. Specifically, we recommend that (a) the Spartan program be expanded and (b) that funding be identified to focus on these smaller payloads across disciplinary lines and to broaden the participation from the science community.

The Spartan is a 1-2 meter-sized "box" into which a science instrument can be packaged. It is set free from the Shuttle where it functions autonomously for up to 40 hours storing scientific data on its tape recorder. It is then retrieved by the Shuttle and returned to the experimenter. The current Spartan program is a low-cost program which builds on the successful sounding rocket research program, offering 30 hours or more of observing instead of the few minutes available on a rocket flight. The first Spartan is scheduled for flight in August 1984. We believe this program has great potential for involving many research groups in experiments from earth orbit at modest cost.

Increasing the opportunities for small and mid-size flight experiments on Shuttle is one of the recommendations of the NASA/University Relations Study Group.

Last year we complimented the work of NASA's Space System Exploration Committee in defining a long-term program which the community could support. At that time we suggested that the formation of a survey committee to formulate a prioritized set of objectives spanning a similar period of time and encompassing all disciplines of Space Science would strengthen NASA's program. This is a suggestion that bears repeating. A long-term "core program plan" in space science would be welcomed by us all.

The NASA space sciences program, if sustained, promises an exciting scientific return in the late 1980s. But what of the present? Will there be trained scientists ready and able to analyze the wealth of data in the late 1980s and the 1990s? The last planetary encounter was in 1981 (Voyager Saturn); the next will be in 1986 (Voyager Uranus). No space science spacecraft will be launched in 1984. It is the basic research and analysis (R&A) program which maintains the space sciences program. In our testimony to you last year we underscored the importance of a strong basic research program. Unfortunately, the FY 85 NASA Space Science and Applications budget proposed by the Administration is deficient in this area.

The planetary exploration R & A is down 13% from last year, and the physics and astronomy R & A is down 5% after inflation. In the planetary program it is generally agreed by those inside and outside NASA that the FY 81 R & A represents a minimum level for a healthy program. Thus, there is a $15 million shortfall in the FY 85 budget. Addition of this $15 million would bring the planetary exploration budget close to the $300 million (FY 84 $) level recommended by the SSEC.

The funds in this area support many vital projects, including: the world's finest infrared telescope, the Lunar Curatorial Facility for the preservation and study of lunar samples and Antarctic meteorites; continuing analysis of the Voyagers Jupiter and Saturn data; mission operations and data analysis for Pioneer Venus and for Pioneers 6-11, still transmitting valuable data on the distant parts of the interplanetary medium; salaries of several hundred scientists; support for graduate students; theoretical and laboratory studies; regional space imaging facilities to make available for further study the wealth of images obtained from two decades of space exploration; the International Halley Watch - a unique world-wide effort led by the U.S. to coordinate and

archive the observations of Comet Halley in 1985 and 1986; international cooperation on various European space projects including the ESA Comet Halley mission; studies for future missions such as the gravity probe, and the comet rendezvous. In short, everything that turns a string of binary bits transmitted by a spacecraft into new scientific knowledge is funded via the research and analysis line items.

Furthermore, NASA's own University Relations Study Group recommended an infusion of $11 million in FY 85 to upgrade laboratory equipment and an additional $14 million increase for data analysis in the Astrophysics and Planetary Exploration program ($20 million increase for data analysis in OSSA[1] altogether). Not only do university scientists participate in space flight experiments, data analysis, and related theoretical and laboratory investigations, but they are also the essential conduit in transferring new knowledge and technology to other elements of our society through the education and training of students.

Basic research funding has been declining steadily in recent years. The urgent need for new funds to upgrade laboratory equipment in the physical sciences at universities and to reverse the erosion of basic research support has been articulated by the President's Science Advisor as well as by members of Congress. The United States can not hope to maintain its leadership in science and technology without responding to this need within each of the relevant federal agencies. We call upon the Congress to augment the research and analysis line items in the OSSA FY 85 budget. As a minimum, we recommend $15 million increase for planetary exploration R & A and $11 million distributed among the disciplines for upgrading university laboratories.

The FY 85 OSSA budget is a positive one in most respects, and we are optimistic about the future and continued U.S. leader-

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[1] Office of Space Science and Applications

ship in Space Science. Because of the long hiatus in new missions, there are still several important projects awaiting new starts in subsequent years including the Mariner Mark II program, with a comet rendezvous mission scheduled for a new start in FY 87. We also encourage NASA to explore avenues of international cooperation. It is crucial that sufficient research and analysis funding be supplied to support current scientists and encourage young people to enter the fields.

In the area of Space and Terrestrial Applications, we continue to support the strategy of transferring mature capabilities to other civil or commercial operators and users, as appropriate. In this regard we welcome initiatives to promote commercialization of launch vehicles. We have consistently noted that it is essential that the government, and specifically the NASA, continue to lead the development of advanced remote sensing instruments. Such development efforts should be continued.

The evolution of the U.S. space materials processing program has been slow. This is the area to which President Reagan referred when he spoke of research in "metals and life-saving medicines which can be manufactured only in space."

Since 1980, NASA's budget for MPS[1] projects has been relatively constant (approx. $23 million per year) and can best be described as marginal. The development of space industrialization is heavily influenced by the level of government commitment to space. Currently, only a small handful of companies are engaged in advanced research and development in the MPS field. Although there is the promise of profits to be made, most companies remain reluctant to commit R&D dollars until the Federal government demonstrates its own commitment to the commercialization of space. In an environment of high technological uncertainty and market risk, most investors and corporate planners consider stable government policies and commitment to basic infrastructural

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[1] Materials Processing in Space

services prerequisites to significant corporate investments. The present low level of support, constraints in adding additional qualified scientists, and delays in flight hardware starts have been a deterrent toward building industry confidence.

Despite the U.S. government's stated desire to strive for commercial self-sufficiency in the field of materials processing in space within the decade, it is inconceivable that federal financial involvement could be eliminated within that time frame due to the large front-end investment required to bring MPS products in the the market-place. Therefore, during the foreseeable future, the U.S. government must continue to assume the role of providing funding and promoting specific programs. The government must also be looked upon to facilitiate the development of MPS facility-class payload hardware, and the generation of ideas and concepts which are appropriate for commercial applications. This situation can be greatly improved with the availability of a manned space station if policies are established for working in the facility which are consistent with industries' needs and goals.

In summary, NASA should continue to support materials research at an increased level of support, and should plan for materials research as a part of the space station capability and establish reasonable policies for use of the facility by industry.

In considering the importance of the NASA Advanced Communications Technology Satellite (ACTS) program it is germane to recall some of the statements made in the AIAA official position paper of February 16, 1976, on "The Federal Role in Communications Satellite R&D":

> From 1960 to 1973, the federal government (primarily NASA) took the dominant role in Communications

> Satellite Research and Development (R&D), thereby providing the basis for low-risk operational system development by private enterprise in the 1960s and 1970s.....During the years since the 1973 NASA disengagement from an active R&D role, private industry has not assumed a broad-scale R&D activity..... Active and ambitious programs are now being sponsored by foreign governments, particularly in Japan (the CSE and BSE Programs), in Canada (the CTS Program), and in Europe (the Symphonie, OTS, MAROTS, SIRIO and others). Each of these countries now has a government-sponsored communications satellite R&D budget several times greater than the United States.....The federal government should reassess its communications satellite technology R&D role, particularly supporting synchronous spacecraft flights such as new families of Applications Technology Satellites (ATS). Although some new technology can be tested adequately on the ground prior to operational deployment, a major portion of the necessary new technology requires R&D orbital test data on performance and lifetime to provide acceptably low risk prior to initiation of an operational program. In particular, synchronous-orbit flight testing is required to provide realistic mission demonstrations."

Consistent with this statement, and with the anticipated need for more capable future systems (A/A, Nov 83), AIAA is on record in prior Congressional testimony in support of the ACTS program. AIAA continues to support the ACTS program as originally structured. As private sector initiatives are developed which adequately cover aspects of these technologies, a re-examination of program content may be required.

In particular, we feel that the following high risk areas of advanced communications technology now being developed in the ACTS program are vital to U.S. interests:

- Electronically-hopped spot beams
- Associated on-board message-level switching and processing
- Time Division Multiple Access
- High capacity circuits
- Rain fade compensation methods

Moreover, as in previous testimony, we believe that flight demonstration of these technologies is in our national interest. Since it is likely that European and Japanese vendors will be able to offer flight-proven ACTS-type systems in the same time frame, U.S. suppliers must have a flight-demonstrated capability to remain competitive. Certainly continued U.S. leadership in the field of space communications - the vanguard of space commercialization - is consistent with both Adminstration and Congressional guidance.

For these reasons, the AIAA believes that the ACTS program should maintain its original course, which will require a significant increase over the proposed FY 85 funding, in order to maintain the current technology development momentum and protect the option for a timely flight demonstration.

The usefulness of NASA's Technology Utilization has clearly demonstrated that these relatively small efforts have brought NASA-developed technology and services to the non-aerospace private sector, furthering the Administration goal of rebuilding the nation's economy through technology development. The AIAA has participated through a program which has brought more than

600 non-aerospace R&D executives from over 300 "Fortune 500" companies face-to-face with NASA specialists in a wide variety of subjects. To illustrate this point, I would like to enter into the record at this point a statement of Mr. James A. Graham of Deere and Company regarding his company's experience with the AIAA program (A/A, Feb 83).

When President Keagan recognized what "opportunities and jobs will multiply as we cross new thresholds of knowledge" and spoke of the space program creating sunrise industries and making older ones more competitive, we feel he was referring to the kinds of interactions we are fostering. This program deserves your continued support.

Before leaving the area of Science and Applications, there is one more point which must be noted. We have cited "balance" as a criterion of an effective space program. We therefore applaud the balance NASA has struck between the Science and Applications programs and other flight activities. We concur that this balance should be maintained into the future.

It is especially important that Science and Applications programs fully benefit from the Space Station. Certainly the biomedical and materials sciences should make good use of these advanced capabilities, and remote observations should be enhanced, if instrument programs are supported. We will continue to be keen observers of how well NASA and the Congress maintain the essential balance within the NASA budget as the Space Station program evolves.

With that comment, I would now like to turn to the area of Space Transportation.

During the past year, the Shuttle has moved closer to a true

operational capability. Obtaining such a capability must continue to be NASA's highest priority. This will help maintain a leadership position in the 1980s and meet critical national needs. With the advent of the Space Station a major role of the Space Shuttle will be that of transport vehicle. The Shuttle will take the Space Station elements to orbit and, with Shuttle flight crews, assemble and activate the Station. The Shuttle will subsequently become the primary means of servicing the Station with crew replacements, delivery of expendables, and up and down cargo for the projects conducted on and around the Station.

A more near term role for the Shuttle Orbiter wil be that of an on-orbit test bed for developing Space Station era technology components, subsystems and system elements. Between now and the time of the Station's operational capabilities the Orbiter can also be used to gain valuable experience in on-orbit operational techniques. Operations such as fuel transfer, assembly of structures, extended periods of extravehicular activity in simulated repair missions and rescue are other examples of experience that must be gained.

In addition to its payload delivery role, the Shuttle can contribute to developing the user constituency for Space Station. In the sortie mode, the Orbiter is in fact a Space Station. In this mode, all Space Station mission projects, manned or unmanned, can begin their development almost immediately by using the Orbiter as their precursor Space Station. The STS-9 Spacelab mission has shown that the Orbiter, as configured for that flight, could likely fly a 12-day mission. With the addition of a set of fuel cell cryogen kits mounted in the payload bay, a 20- to 25-day mission is possible. The investment to achieve this extended duration capability for the Orbiter is approximately $60 million. If approved in FY 85 these missions utilizing the Orbiter can begin in calendar year

1987. This would give us five years of extended on-orbit operations capability before the initial Space Station becomes operational; extremely high-value capability for the investment required.

We have consistently held the opinion that an investment which retains the option for an additional orbiter would be wise. We believe it is likely that:

- Flight costs of STS operations will drop as the full fleet comes on line and experience increases,
- The nation will come to rely on the STS for many critical missions,
- Fleet size must account for potential outages,
- Scientific, commercial and other uses of the orbiter will require longer on-orbit stay times and more flexibility than currently planned, and
- The overall demand for space launch service, including support for a space station, will increase over the next two decades.

These factors all point to the likely need for a larger fleet. The capability to produce orbiters is a national asset that has taken 12 years to develop. A viable, economically operated Shuttle fleet is also a national asset that can be this nation's means to the leadership in the frontier of space. The U.S. civil government, industrial entrepreneurs, and the military will use these assets to achieve their objectives over the next twenty years.

With the delivery of the Orbiter Atlantis in December of 1984 the Shuttle Orbiter production contract will terminate. As this event draws near, the contractor base to support Orbiter production is rapicly eroding. In FY 84 an Orbiter structural

spares program, coupled with the approved Orbiter Logistics Support Program, was intended to protect the program's contractor base.

However, to date the production of orbiters has been the prime source of spare parts to support STS flight operations. The approved logistics program will not support flight operations without a production base until 1987. Thus, without continued production, achievement of operational effectiveness is in jeopardy. Of greater concern is the ability of a four-orbiter fleet to support the growth in requirements for the Shuttle's unique mission capabilities.

It is therefore now essential that the government, with help from the Shuttle industrial team, define an Orbiter Production and Operational Support Plan for a 15- to 20 year program. Orbiter build schedules can be defined at a minimum rate necessary to maintain the contractor base for production and major repair and overhaul over the extended period of time. A similar program for logistic support should be defined to accommodate the high potential of Shuttle flights in excess of 30 flights/year.

Any system that is committed to supporting long range national objectives as is the Space Shuttle must have the government's commitment to insure its capabilities and operations support for the duration of its useful life. The time for making the decisions to reflect these commitments is now. Within the next year the production base for orbiters will begin to erode dramatically. The government's approval to develop a long range support plan and commit to it, is essential in this crucial period.

As I noted earlier, we were very pleased that the President has directed NASA to proceed with a manned space station. We have consistently supported an evolutionary program to make best use of humans in space. International participation in this endeavor is a strategy we support.

During the past year, there have been numerous studies and testimony taken to determine the uses and purpose to be served by a United States Manned Space Station. Of all of the arguments, we feel two are most persuasive.

First, a Space Station will serve as a National Laboratory for both government and industry to conduct research and development utilizing the space environment. Such a laboratory will provide the capability to examine the benefits of micro-gravity on pharmaceutical and semiconductor production and to develop the techniques and tools for on-orbit satellite servicing to name just two examples of the many possibilities. This laboratory capability is analogous to the NASA wind tunnels that are used at their operating cost by U.S. industry to develop new generations of aircraft. No individual contractor could afford to capitalize such a facility, but the availability of the wind tunnels to the U.S. industry has been a significant factor in this country's world-wide leadership in aeronautics. As we can reflect on the benefits from the use of the wind tunnels to stimulate the nation's aircraft industry, we can look forward to similar benefits from a National Laboratory in space. This capability is clearly an important step in the future industrialization of space.

Second, and most important, the commitment to a Manned Space Station is a statement of national will and a commitment to continue to pursue high technology leadership, which is vital to continued national economic growth. We endorse this commitment and urge the Congress to recognize the value of such an activity to the stability and vitality of the Nation. There can be no more fitting tribute to the American vision than the beginning of a permanent presence of U.S. citizens in space in 1992, the 500th anniversary of Columbus' historic voyage.

A balanced program for our national space operations capability should also include planning for advanced launch vehicles and orbital maneuvering and transfer capabilities. We therefore strongly support on-going studies of ways to meet future earth-to-orbit transportation needs.

As we remarked last year, effective operations in low earth orbits will require an orbital maneuvering vehicle (OMV), which would first be used in conjunction with the Orbiter to transport fuel to nearby satellites or bring the satellites back to the Orbiter for fueling or servicing, thus extending the satellites' operational life. An improved OMV would perform other in situ operations with satellites in orbits up to 800 nm, and would be a useful tool in on-orbit assembly operations, including the assembly of the Station itself. Once the Station is operational, the OMV will be the primary mode of transportation between the Station and unmanned platforms, mini-factories in space, or research platforms operating in the proximity of the OMV. The continued funding of this program is essential to provide a vital link in our space transportation system. With funding approval, the Orbiter-based OMV could begin operations in calendar year 1987 in support of extended duration orbiter operations and later Space Station construction.

Similarly, our support of an Orbit Transfer Vehicle (OTV) development program remains strong. To assure compatibility between the Space Station and the OTV, the FY 85 plan for an OTV requirements and concept design study should be supported. Funding for Phase B studies should begin in FY 86. Only on such a schedule would an OTV be available to operate in the Space Station-based mode within a year after the Station becomes operational.

I would now like to turn to the Space Research and Technology

portion of the budget. We have consistently pointed out that this is the area we consider to be the heart of NASA's and our country's future civil space capabilities. As was the case last year, Space Station planning continues to be a major emphasis in this area (A/A, Mar 83). It is therefore appropriate that we repeat our last year's warning that overemphasis on space station-related technology development without a clear concept of the requirements or design constraints may jeopardize other worthwhile opportunities.

This caution is especially appropriate in a budget which has only a small allocation of funds for advanced technology development in the Space Science and Applications, and Space Transportation areas.

NASA planning should also draw on past experience to help maximize the applicability of current technology efforts to future space station design (A/A, Feb 83).

For several years we have expressed specific concern about support for advanced liquid rocket propulsion technology. Last year we published an Institute position paper citing specific areas of national weakness in this vital technical field (A/A, Apr 83). As you know, many space technology advancements take years from concept inception to fruition. Perhaps none has a longer lead time or a more intense impact on system costs and capabilities than rocket propulsion. We urge continued growth in this critical field, especially in the areas of

- Advanced high chamber pressure hydrocarbon booster engines,
- Cryogenic engine and low-mass tankage for space-based transfer vehicles,

- Pump-fed space storable maneuvering propulsion systems, and
- High-efficiency bipropellant auxiliary propulsion engines.

It will also be important to increase the operating life and reliability of the Space Shuttle Main Engine (SSME), as well as to pursue other improvements to this space launch work horse. (A/A, Jan 83).

Because of the significance of these technologies to future space operations capabilities, I would like to quote from the conclusion of our evaluation:

> "Although the United States has in the past maintained leadership in advanced liquid rocket propulsion systems, the nation's liquid rocket propulsion capability has now declined to a critically low level and may soon be inadequate for the development of advanced systems needed to utilize space in our national interest. The fundamental lack of preparedness in this area, caused by the absence of an adequately funded technology and development support base, leaves the U.S. without the capability to properly pursue the next and succeeding generations of space vehicles."

Other key technology areas in which adequate NASA support is essential include:

- Space power systems, especially the SP-100 nuclear reactor power program,
- Large structure control and testing (A/A, Oct 83),
- Spacecraft autonomous operation (A/A, Jul/Aug 83),

- Magnetohydrodynamic (MPD) thruster life improvements, and
- Aero assisted orbit transfer techniques (A/A, Nov 83).

Overall, the Research and Technology program is being well supported.

In conclusion, Mr. Chairman, we feel that the NASA space program is relatively healthy and well balanced. The fiscal and programmatic stability which was lacking in past years now appears to be firmly ingrained in the planning process. These two criteria (balance and stability) are being satisfactorily met.

But the degree to which the NASA program measures up to our third standard, perspective, is hard to assess. With the noteworthy exception of the recommendations of the Solar System Exploration Committee, we find no long range plan, no vision, by which today's activities can be measured. As I mentioned earlier, without such a long range perspective, the adequacy of current plans defies assessment; with it, new opportunities become clear (A/A, May 1983, "Why Billions Can and Should Be Spent On Space").

We recognize that priorities change, and perspectives clear with time. But we feel that a national long-range space program plan could be a dynamic, living strategy without violating our call for stable commitments.

Of course, the AIAA is eager to participate in the national process of setting the long-range goals which follows such a commitment. Based on our presentation to the Space Caucus, numerous internal studies and assessments and the energy of our membership, we have begun to address alternative courses, including renewed activity on the moon (A/A, June 83). Let us join together to build and maintain a consensus regarding our nation's future civil space activities. Within such a vision, we shall all advance.

Mr. Chairman, that concludes our prepared remarks. We would, of course, be happy to answer questions.

Technology Transfer: A Case History of Success

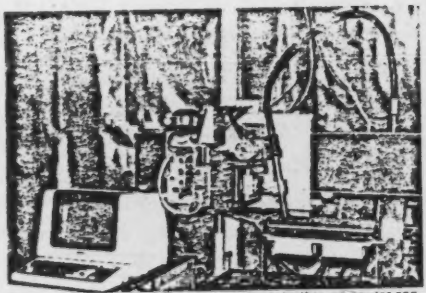
By JAMES A. GRAHAM
Deere & Company

From the AIAA program to promote greater interaction between NASA and nonaerospace industry that began three years ago (see article on page 68 of this issue of *A/A*), Deere & Co. has garnered substantial benefits. We participated in all the visits to NASA research centers, and from them and AIAA consultants identified NASA engineers and scientists to approach for in-depth discussions on many topics. These discussions have aided us in achieving several important objectives.

Cast-Iron Solidification: In July 1981 Deere signed the first Technical Exchange Agreement between NASA and an industrial partner. The agreement provides for joint research into the effects of zero-*g* on solidification of cast iron, particularly graphite growth mechanisms, diffusion phenomena, and constituent segregation. Tests have been conducted on both KC-135 and F-104 aircraft. This project, carried out with the Materials Processing Office at NASA Marshall Space Flight Center, has made our scientists more aware of the influence of gravity and has resulted in our programming an effect of gravity on the temperature-time curves into our computer simulation of casting cooling.

Ceramics: NASA-Lewis gave our staff a review of ceramic coatings on metals and nondestructive evaluation of monolithic ceramics. One of our staff returned to NASA-Lewis for in-depth discussions. This greatly aided us in establishing a laboratory for depositing ceramic coatings on metal parts. Several parts are now under field-test to determine the increase in wear life.

Chemical Vapor Deposition: A Deere staff member toured the NASA-Lewis facilities for deposition of coatings. This aided us in designing a new laboratory for chemical vapor deposition. It is now about ready for operation.



Deere has integrated NASA technology into this computer-controlled gas metal arc welding system it has under development.

Graphite-Reinforced Plastic Composites: At NASA-Langley two of our managers reviewed work on the manufacture and evaluation of graphite-reinforced plastic composites. Then, the November 16 and 17 materials seminar at Langley (see article on page 68) provided a chance for them to become acquainted with other NASA specialists on composites. They brought back additional ideas for manufacture and inspection of composites.

Nondestructive Testing (NDT): A NASA-Langley engineer visited the Deere Technical Center to present a seminar and discussed NDT with our specialists. His presentation gave us new insights and influenced our activities in NDT. As a consequence, we would like to get NASA-Lewis to participate in a foundry-industry joint study of cast-iron properties. The industry participants are measuring several properties of cast iron and wish to correlate their results with NASA's ultrasonics tests.

Welding Automation: In visits to NASA Jet Propulsion Lab, two of our staff observed its work on robotics and computer-vision systems and have applied this knowledge to equipment in our laboratory for research on welding automation.

JAMES A. GRAHAM is senior research associate at Deere's Technical Center in Moline, Ill. Earlier at Deere he was manager of reliability and manager of materials technology. Graham chairs AIAA's Corporate Associates Committee.

Energy Management: Engineers from Deere's Component Works have met with energy-management experts at NASA Headquarters. They reviewed several areas of *mutual* interest and activity, such as energy-management facilities, solar applications, and power-factor controllers. A continued exchange of information is expected.

Fatigue: NASA-Lewis presented a seminar at our Technical Center on fatigue-creep interaction. It increased our knowledge of this phenomenon, and the NASA knowledge is being incorporated in our life-prediction procedures.

Diesel Fuel: Our staff keeps in touch with NASA-Lewis on future fuel properties for diesel engines. We need this for engine planning.

New Mechanical Component: One of our engineers was working on a new mechanical component that required an adhesive bonded joint, a technology new to Deere but routine to NASA. The problem was joining heat-treated 4130 steel to 17-7PH stainless steel, which was selected with the aid of NASA. Langley personnel conducted a routine analysis of the design using an existing finite element model program. With their suggestions on design, surface preparation, and methods of adhesive application, a fatigue life improvement of 10-fold was achieved. Prototype assemblies passed the initial test satisfactorily.

Overall Program with NASA: As I reflect on the NASA-Deere activities over the past three years I see much communication taking place. At first it was through the AIAA planned tours of NASA research centers. With the aid of the AIAA Corporate Associates Program we developed contacts both at NASA Headquarters and the research centers. Now several people in the Deere organization feel free to communicate with NASA personnel.

It is very gratifying to observe this progression of Deere interaction with NASA. I was feeling that we had done about all we could to promote exchange of information between industry and NASA. Then two of our managers returned from the NASA/AIAA Advanced Materials Seminar at NASA-Langley last November with enthusiasm about what was presented and the contacts they made with NASA personnel. I anticipate they will make more good things happen through contact with NASA engineers and scientists.

This experience at Langley indicates the desirability of special-interest seminars. Similar seminars should be planned by NASA/AIAA in the future—on subjects that can have broad application, such as an update on other materials, human factors, high-temperature materials, heat-insulating materials, and controls.

GENERAL DYNAMICS CORPORATION
Pierre Laclede Center
St. Louis, Missouri 63105

314-889-8200

ALAN M. LOVELACE

Biographical Sketch

Effective 27 August 1982 Dr. Lovelace was made VP-Productivity & Quality Assurance.

Dr. Alan M. Lovelace joined General Dynamics Corporation as Vice President-Science and Engineering in July, 1981. He had served as Acting Administrator of the National Aeronautics and Space Administration since January of 1981.

Dr. Lovelace joined NASA in 1974 as Associate Administrator for the Office of Aeronautics and Space Technology. He was named Deputy Administrator in June 1976 by President Ford.

Since entering federal service with the U.S. Air Force in 1954, he has held many research management positions. He served at the Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio, from 1954 through 1972, having been named Director in 1967.

From 1972 to 1973, he served as Director of Science and Technology with the Air Force Systems Command, Andrews Air Force Base, Washington, D.C. From 1973 to 1974, Dr. Lovelace was Principal Deputy Assistant Secretary of the Air Force for Research and Development.

Dr. Lovelace retired as Deputy Administrator of NASA in December 1980 but stayed with the Administration through the first flight of the Space Shuttle Columbia and the appointment of a new administrator.

Born in St. Petersburg, Florida, in 1929, Dr. Lovelace received bachelor's, master's and doctoral degrees in chemistry from the University of Florida. Awards he has received include the Presidential Citizens Medal, the Department of Defense Exceptional Service Medal, the Air Force Decoration for Exceptional Service, the National Civil Service League Career Service Award, and the Office of Aerospace Research Award for Outstanding Contributions to Research.

He is a Fellow of the American Institute of Aeronautics and Astronautics and the American Astronautical Society, and is a member of the National Academy of Engineering, Air Force Association, Sigma Xi and Phi Beta Kappa.

Married to the former Kathryn Logan of Bridgeton, Connecticut, the Lovelaces have two children.

# # #

Revised: 10-27-82
January 1982

DAVID J. ROHRBAUGH

David J. Rohrbaugh has been a member of the AIAA since 1979 and is presently Vice Chairman and Chairman elect of the AIAA Space Systems Technical Committee. He served on the National AIAA Nominating Committee for 1982-1983 and will be Chairman of the Space Systems Technical Committee for 1984. He was panel chairman for the USAF Technology Workshop in 1981 and will chair the session on Advanced Space Transportation Systems at the 1984 AIAA/NASA Space Systems Technology Conference.

Mr. Rohrbaugh came to The Boeing Company in 1959. He received his BSME from the University of Washington in 1963. His assignments with Boeing have been in the Space Systems area, initially with Burner II Mission Operations and including Space Systems Divisional Marketing Manager; Space Transportation Futures Manager. In 1979 he became NASA Inertial Upper Stage Program Manager and is presently the Mission Integration Manager for the Inertial Upper Stage Program.

He has presented many papers for the AIAA, IAF and JANNAF. The most recent were papers on the Inertial Upper Stage presented at the IAF in 1980 and 1981.

Mr. Rohrbaugh is active in community affairs and his hobbies include travel, golf, tennis and skiing. He and his wife, Colleen, have three children.

Mr. VOLKMER. Thank you very much.

I recognize the gentleman from Washington. Do you have any questions?

Mr. CHANDLER. Not right this minute, thank you, Mr. Chairman.

Mr. VOLKMER. The gentleman from Florida.

Mr. MACKAY. Your conclusion that there is no long-range plan, no vision by which today's activities can be measured, that's a pretty strong statement. Your suggestion would be that we spell out not only a long-range plan, but I believe you said a time schedule for meeting that plan. Is that accurate? How would you do that? Who would be involved in that effort?

Dr. LOVELACE. I think, Mr. MacKay, if I might respond to that initially and then Mr. Rohrbaugh may wish to——

Mr. MACKAY. Dr. Rogers made this same observation the other day.

Dr. LOVELACE. I think that our comment, Mr. MacKay, must be taken in the context that there obviously are some long-range programs that have been undertaken in the past and are currently in work in this country in the space arena, and principally in NASA, but I think that what we would like to see is a broader context of a plan, a tapestry that embraces several years into the future and shows the interrelationship of the activities that we have underway and those that we plan to put in place and a time schedule; not so much that plans are drawn up to be worshipped and followed inevitably in the following years, because there will be changes, but we will have a baseline from which we can measure, one, our progress, two, our changes to that plan which will inevitably take place. In a sense that plan then represents a national commitment to this broad endeavor that we have undertaken for some years now of utilizing, exploring space.

I don't know whether you would like to——

Dr. ROHRBAUGH. I would like to just comment on one area, which happens to be an area of expertise with me, and that is space transportation. We spent a lot of time debating whether we're going to have a fifth orbiter or not. Some of us wonder where the sixth, seventh, and eighth are going to come from, or what our transportation system will be in the year 2000. We don't see that perspective and planning going on, and that's an example of the kinds of things that I was talking about.

Mr. MACKAY. One of our witnesses yesterday made the point that there are two dangers associated with the space station. One is that we might find a recurrence of what happened with the shuttle, that they had to scavenge funds from other programs to keep the shuttle running because of a lack of a commitment, and the other being that the space station's existence might then skew our priorities later on toward programs in which the space station was involved and away from programs in which it was not. Having a long-range plan and some benchmarks would be one of the best guarantees against that kind of thing.

You have mentioned that NASA is still not heeding the need for basic research support, despite the fact that Congress and many advisory committees have recommended increases. How, in your opinion, would be the best way for us to get NASA's attention on that subject?

Dr. LOVELACE. Well, Mr. MacKay, I think that I must plead being a novice on how to advise the Congress in terms of getting agencies' attention, but I think that in the budget process it might serve the purpose of this committee and its sister committees, increasing those parts of the NASA budget that deal with this issue, and I think those increases in terms of real, absolute dollars need not be large. I can testify with some experience that those actions are viewed by an agency like NASA as very important messages which I am sure, as they have in the past, they would respond to in a very constructive way, and I suspect they would do the same in this area.

Mr. MACKAY. You had some data, and I'll find it in a minute, which indicated that in the area of research—it's on page 9 of your prepared testimony:

> The planetary exploration research and analysis is down 13 percent from last year, and the physics and astronomy research and analysis is down 5 percent after inflation. In the planetary program it is generally agreed by those inside and outside NASA that the Fiscal Year 1981 R and A represents a minimum level for a healthy program. Thus, there is a $15 million shortfall in the Fiscal Year 1985 budget. Addition of this $15 million would bring the planetary exploration budget close to the $300 million level recommended by SSEC.

This is really a specific example of the failure to support basic research? Is that what you're saying?

Dr. LOVELACE. I think that this is an example of an area in the space science program, Mr. MacKay, where the budget seems to be in our judgment a little bit marginal, and I think we rely very much on the advice of scientists who are working in this field and on whom we draw our knowledge about what would represent a useful level of activity. I think Dr. Rohrbaugh may want to amplify on this, since he is involved in that process with AIAA's technical committees.

Dr. ROHRBAUGH. Yes; I would like to comment. At least let me remind you some of what is supported by these funds. The world's finest infrared telescope was the lunar curatorial facility for the preservation and study of lunar samples and antarctic meteorites; conducting analysis of the Voyagers of Jupiter and Saturn data; mission operations and data analysis; these are the kinds of things that are supported by that activity, and we find it distressing to see that those elements of this budget are being reduced and not sustained.

Mr. MACKAY. You are speaking for an institute which has over 34,000 members and spans a broad spectrum of all of the sciences and technologies having to do with space, and it seems to me that you are making a criticism that deserves a great deal of attention. It seems to me that that criticism is that we are pouring more money into the program but we don't seem to have any rational design to the program, or any benchmarks by which people can test whether we're getting our money's worth, or any clear aim as to where we're headed.

Does your membership have any concern about the militarization of NASA? Do you see that as having anything to do with the failure to outline clearly, in terms of a civilian space effort, what our priorities are? Is the mixture of the civilian and the military priorities part of the problem?

Dr. LOVELACE. Mr. MacKay, I have to say that to my knowledge we, AIAA, have really not addressed the question of, as you put it, the militarization of NASA.

Mr. MACKAY. The militarization of space research.

Dr. LOVELACE. Of space research. But I would tend to say that I personally don't believe that that is a contributing factor, if it is real, that it is a contributing factor to our inability to lay out a NASA program. It is obviously a part. The military applications of space and the research and development that they must conduct in space would be part of a national program, if you put it all together, but it isn't clear to me that that is what is preventing us from putting together a national plan.

Mr. MACKAY. Is not the shift of America's research priorities away from civilian research and into military research directly related to the fact that money is being scavenged out of basic science areas which have no potential or known military application? Do you not see that? Is your membership not concerned about that? Is that not a cost, the price that we're paying?

Dr. LOVELACE. I guess I would have to say that if that's happening, we would be concerned.

Mr. MACKAY. Have you followed the shift in where the money has gone in the past 3 years? It's now more than 65 percent going into military.

Dr. LOVELACE. Well, I think we have to look at that in terms of the total expenditure, too. What I think has happened, Mr. MacKay—and I would have to go back and really look at all of the data which you refer to—but I think our total investment, national investment in space has grown over the past 6 to 8 years, at least to my knowledge.

Now what has happened is that because of the applications, the military applications of space, larger amounts of moneys are being invested in that sector, but it is not clear to me that it has been done, that those investments have been made necessarily at the expense of other nonmilitary scientific research.

Mr. MACKAY. It seems to me that that's an inescapable conclusion from your testimony: that although it is going up, the whole space program is going up, there doesn't seem to be any rational explanation of it from a civilian standpoint. That's point one, and point two, R&A, basic R&A is being reduced. I believe that is correct, and it seems to me that all you have done is left some blank spaces and it's impossible—what other conclusion could one reach?

Dr. LOVELACE. Well, let me see, Mr. MacKay, if I can lead you to a slightly different appreciation, at least, for what I think causes the problem. We have been talking some this morning about communications and communications technology. There is absolutely no doubt in my mind that we are in the midst of an information revolution, really, in the United States and in the world, and part of that is in the scientific community. We are able today to collect an awful lot of data very quickly, just a monumental amount of it. In fact, it happens to each one of us in our daily life whether we want it or not. We're almost deluged with it.

Now the problem is, we need to spend time getting the information out of the data, and we tend many times not to make investments because those investments for the most part don't have a

very tangible hardware feature about them. We tend not to think about supporting scientists who are analyzing literally reams of data that has been made available.

That's a very, frankly a very much easier thing to reduce. It is very hard to reduce some commitment to build a large physical object, if you will. You get two-thirds of the way through that and say, "Well, let's reduce it," and you suddenly find you don't really—you really have not achieved the goal at all. You don't just get two-thirds of it. You actually end up getting zero, so we commit ourselves and we follow through.

The commitment to the mental resources, to analyze data, to do the scientific inquiry based on the data and information that we have, is a much easier thing to reduce; a much more difficult thing to increase, and even if you leave it at the same level and as inflation begins to erode it, that's an easy thing to do. I think that's frankly one of the reasons, at least in my experience, and it's a more difficult thing to defend, as witness my trying to defend the investment of some dollars to support some scientists to continue to analyze data and information and material in the case of the lunar samples that we have in our hands, because you could very well say, "Well, what will we find out?" And I would be hard-pressed to tell you, because of the nature of scientific inquiry, to tell you exactly what we will find out, and yet I think it's very important that we continue to support and sustain that vital thread, but it has always, I think, been a more tenuous portion of our economy and of our culture.

Mr. MACKAY. As I believe our witness yesterday said, it is difficult to raise this kind of question without feeling the necessity to say that I'm not against NASA. My point is, this committee has jurisdiction over civilian space research, as I understand it. That's the limit of our turf. The problem is that civilian space research is part of an overall effort, and it seems to me that your testimony is saying our civilian space research priorities don't make sense or they are nonexistent.

Dr. LOVELACE. I would have to say, Mr. MacKay, that we're not saying that the programs that are contained in the budget which we are testifying on here today are not sensible programs. We've given you comments——

Mr. MACKAY. But you have said there is a lack of a cohesive plan.

Dr. LOVELACE. What we are saying is that there is a lack of a long-range and cohesive plan that is, in fact, the fabric which these various threads that we talk about are woven into, and we know where they lead. We know what our plan is. As I said earlier, planning does not necessarily commit us to the execution of that in its finite detail but it does allow us to know where we thought we were trying to get to when we started, and how we had to change that because of either budgetary priorities or because of technical problems that we encounter. I think it's that longer range plan that is really not evident to us.

Mr. MACKAY. The lack of that makes it more difficult for us to wall off basic research and science against the encroachments of, as you said, big glamorous objects that are being built.

Dr. LOVELACE. I think that it does. I think it makes it—one must view each program, in a sense, out of context.

Mr. MACKAY. It also makes it more difficult for us to encourage industry to participate, since they look and they say, "We can't tell where you're going and we don't see that there is any stable commitment."

Dr. LOVELACE. I think that that's true. I think Dr. Young made that point very eloquently, that many times the constancy and the commitment is almost more important than the absolute amount of money.

Mr. MACKAY. In fact, that's your testimony on page 11 in the materials processing in space:

> Although there is the promise of profits to be made, most companies remain reluctant to commit R&D dollars until the Federal Government demonstrates its own commitment to the commercialization of space.

Am I misreading that?

Dr. ROHRBAUGH. No; that is true. I think that we are finding within industry, and particularly even within my own company, that the risk is too great for a company to venture out in the materials processing area without more assistance than just the joint endeavor agreement that NASA offers. We've got to get some basic research work done and some laboratory work done to enable industry to get to the point where they feel that the capital that they have to put forward is worth the risk that they're taking in a new process, and that just isn't happening. Therefore, we see only one right now, really—other than Johnson and Johnson—one new endeavor in materials processing, and that is microgravity research on the gallium arsenide crystals, but that doesn't seem to be moving anywhere because nobody wants to put capital behind it because the risk is too high.

Mr. MACKAY. So, in fact what we have is, we are moving our priorities strongly in the direction of competing militarily with the Soviets and the cost of that, it seems to me, is that we are not keeping our competition up in the area of civilian space research, which is almost like a catch-22. So our economy becomes weaker, we have less money, there is more pressure. The pressure results in taking more out of the civilian space research so that we can continue to compete with the Soviets. Is that not an inescapable conclusion?

Dr. ROHRBAUGH. I'm not sure. I would like to make——

Mr. MACKAY. I think you also would like us to balance the budget.

Dr. ROHRBAUGH. Yes; I would like to make a comment in that area, because I think that there is basic technology research that is done by the military that is applicable to civilian systems, and there is technology research in space obviously done by the civil side that is applicable to military.

One of the things on our agenda for our AIAA Space Systems Committee right now is to discuss a national technology plan, in other words, integrate the whole thing. Our committee——

Mr. MACKAY. That is precisely the weak spot today. There is nobody that is putting things together in a cohesive view of where this Nation should be going so that you can see what the cost is of

continuing to shovel money into a star war and other advanced military research.

Dr. ROHRBAUGH. Yes; I understand that. I can't say where our activity is going to go, but at least our committee has gotten concerned to the point where we are starting to look at that.

Mr. MACKAY. Is your activity going to look at the whole picture?

Dr. ROHRBAUGH. Yes; it is. We have been a fairly strong party in both areas. We kicked off what is referred to as a technology workshop with the Air Force, and through that our committee has gotten a pretty good understanding of what they're doing, and we're holding a technology conference and have been involved with the technology people in NASA, and now it's a matter of putting that together and seeing how it fits from our perspective.

Mr. MACKAY. Do your companies see any risk to you of trying to open that question, in the sense that you are partially supported by military research yourselves?

Dr. LOVELACE. Well, I guess I can speak for my company and I don't think that we do. I think we would say that anything that we can do with NASA and the Department of Defense in the public interest to understand and enlighten our decision process is the right thing to do, so I would——

Dr. ROHRBAUGH. I would agree.

Mr. MACKAY. Thank you, Mr. Chairman.

Mr. VOLKMER. The gentleman from Florida, Mr. Nelson.

Mr. NELSON. Thank you, Mr. Chairman.

I want to follow up just a little bit on the cohesive plan. Your commentary with regard to the lack thereof, how would this compare to the past, let's say at the time, Dr. Lovelace, that you were the Acting Administrator or when you headed the shuttle program? Give me a comparison of what you think about a cohesive plan back then, with now.

Dr. LOVELACE. Mr. Nelson, it's always very difficult to be asked to grade your own paper in public but I guess I would have to say that during my tenure that we really did not do any better job. In other words, I think that it was—if it's a deficiency today I suspect it was as much a deficiency then. We may not have felt it quite as much, since we were pretty much in the trenches, as you well remember, to bring the shuttle to its first flight fruition. You know, when you're busy bailing the boat you tend not to look at the horizon too much, but I think maybe now it begins to surface again as something that we need to pay attention to.

Mr. NELSON. You speak on page 3 of the key elements being balance, stability and perspective. All right, let's take each one of those elements and analyze it. All right. Where would we measure up and where would we fall short on where we're going on the element of balance?

Dr. LOVELACE. I think that, you know, viewing this budget that these remarks refer to, that it's a reasonably well-balanced budget. Now that is my——

Mr. NELSON. You're talking about between space science——

Dr. LOVELACE. That's correct.

Mr. NELSON [continuing]. And the planning of hardware and the planning for the station, et cetera, et cetera. Is that what you mean?

Dr. LOVELACE. That's correct, and I'm going to ask Mr. Rohrbaugh if he wants to amplify on that because he has been, he and other people have been involved in that assessment at a much finer granularity than I have.

Dr. ROHRBAUGH. Well, only to the extent that in the testimony that I just went through a little earlier, we did commend NASA in terms of the balance between space science and their other flight activities and things that are going on. We feel like in this budget that that balance is existing.

The thing that concerns us is that in the future, especially—and I'm sure you have heard this before—as the space station comes on line, will we lose that balance? Will we start to see the areas that we are concerned about going down in deference to the space station activity? I think that we in our testimony state that we would like to keenly observe that and come back and voice our concern if we see that happening.

Mr. NELSON. OK. How about stability?

Dr. LOVELACE. Well, again let me give you my perception of that, Mr. Nelson, and then Mr. Rohrbaugh can amplify if he desires.

I think that there has been good stability in the funding of the NASA program. Now I have to say that in my personal experience and more recently observing it from the sidelines, that the congressional support has been very stable and very supportive, albeit very questioning, as it should be. Having achieved that, then, it is important that NASA commit itself to certain longer range goals and, you know, with a degree of stability pursue those, not obviously in the face of new knowledge or new data.

Being advised of that, they should reexamine it, but they've got to have, they've got to maintain some persistence. When that happens you really do attract other people and other institutions and organizations to cooperate and work on that because they sense that stability. It's like you and I walking through a graveyard holding hands. We might make it together but I probably wouldn't the minute you let go. I begin to really wonder because there might be some risk in that.

I think we have shown instability in some of our programs in the past, and that I think does not serve us well in the future. We need to persist in that. I think that right now certainly, as Dr. Young pointed out, maybe we have lacked some stability and persistence in the communications technology area. The wisdom at the time when the agency backed out of that said that that was the right thing to do. Probably in retrospect maybe we backed out too far.

Mr. NELSON. All right. How about perspective?

Dr. ROHRBAUGH. May I make a comment?

Mr. NELSON. Sure.

Dr. ROHRBAUGH. I think you can cite several examples of instability, and one certainly is planetary exploration. We were going to launch Galileo in 1982. We have not seen a real long-range plan until just recently in terms of what they're going into with the MGCO mission, and that being a new bus that will be the next generation of planetary missions.

I think there has certainly been an instability in the space transportation area and what we are going to do about it, whether we're going to have an OTV or whether we're not. It seems to get started

and stopped. We started SEPS and we stopped it. If a long-range plan was laid out in these areas, maybe some of those stops and starts would not occur or we would have something, as we mentioned in our testimony, to measure it against.

Mr. NELSON. A perspective?

Dr. LOVELACE. Well, I think that the term "perspective" as I understand it, that we use it in this testimony, is the perspective of our expectations for the civil space program. In part all of these, particularly balance as it relates to perspective, says that we try to represent the views in our review of our membership, which is manifold in the sense that it's industrial, it's academic and Government perspective. That has caused us, I think, to make some comments, specific comments in the testimony regarding certain areas which we spoke about earlier with Mr. MacKay.

Maybe you would like to amplify on that.

Dr. ROHRBAUGH. No, I have no further comment.

Dr. LOVELACE. I think it's a long range. We're trying to give it a longer range perspective, too. We tend—and I say "we" collectively—because we in industry tend many times to take some short-range perspectives.

Mr. NELSON. Mr. MacKay.

Mr. MACKAY. Well, just the testimony about the ACTS program this morning, it seems to me that therein lies an eloquent example of the problem. The Milstar program was just basically an effort to get at technology that was at least similar technology, and the ACTS program we sort of backed away from. The Milstar program is, I guess, complete.

It appear to me that the problem is, the system is moving toward the constituency which can get it the money. You want a long-range plan, NASA is going where it has got to go to get the money. That's the long-range plan. I'm not saying I blame them for that. That's the way life works.

Would we not be better off, in terms of a long-range plan, saying America commits itself to a certain percentage of its GNP or its Federal budget per year for space research or for basic research. The real question is civilian research, it's not space research. The same phenomenon is occurring through the NSF, throughout civilian research.

Would you care to comment on that?

Dr. LOVELACE. Well, let me comment first. I accept, Mr. MacKay, your point is well taken about the pressure that is on the civil research community in general. I think that is of concern. I have some difficulty myself in suggesting that maybe we need to commit a fraction of the GNP. I'm not sure that that is something—I often think about this in the context of, would I like to come and sell that concept to you.

Mr. MACKAY. Let me tell you how you sell it.

Dr. LOVELACE. All right.

Mr. MACKAY. You say we've got two wars going on, and the other war—which is also a star war—is with Japan, Germany, France, and other high-tech nations, and during the past 3 years their percent of GNP going into civilian research has been going up and ours has been going down, and we're losing the war. Pretty

quick we're not going to have enough money left to support the star war where we're competing with the Soviets.

Dr. LOVELACE. I really don't quarrel with that at all. Let me see if I can tell you, though, the thing that causes me to pause, and that is that I would like to see us do as good a job as I believe the Japanese have done in terms of targeting what are the important things for us to do. In other words, we would need, I think, to have a plan: What are the areas in which we think we have the highest leverage to make those investments in?

Mr. MACKAY. Don't we have a plan now? We're going to do whatever it takes to be better than the Soviets. That's our plan, and whatever is left over we're going to put into civilian research, and we're going to wonder why our industry is noncompetitive. Now isn't that a good plan? That's what we're doing.

Dr. LOVELACE. Well, I'm afraid I can't testify, Mr. MacKay, as to whether that is——

Mr. MACKAY. Is your company moving toward basic research or military research?

Dr. LOVELACE. I'm not sure I know how to answer that. We do worry a good deal about the fundamental research, Mr. MacKay, that we carry on. How it gets applied—whether that be for civil applications, as we have examples in our company, or military applications—many times it's hard, it's very hard to tell in advance, and many of those investments that we make in that area end up finding application in both arenas. At the level of basic research, at least as I understand it—and it is always very difficult to get into a discussion about what is basic research—but at that level of abstraction I tend not to think about it in terms of its military or civil applications. We tend to think about it as an area, and how fundamentally good is the research that is being conducted—which is to say, have we got the best people doing that and are we supporting them with the right tools?

Mr. MACKAY. Well, my point would be that I think your company parallels NASA. You do research for people who've got money, or you don't stay in business.

Dr. LOVELACE. Well, Mr. MacKay, you're absolutely right that they represent one of our customers, and if our customer comes to us—if you came to us and said, "We would like you to build a bus"—we would give it serious consideration. And so I think it's true of most companies that are in business, if they stay in business they have to be listening to the customer.

Mr. MACKAY. So the lack of a policy, then, or the development of a policy which is skewed toward military applications, then drives the whole system. It drives NASA and it drives the private sector as well.

Dr. LOVELACE. Well, it is certainly true that for those of us who come from companies who do a good deal of business with the Government, that how the Government and how the Congress chooses to apportion its money has a profound effect upon where our business—how our business shifts. I don't think there's any question, and the same is true in our civil markets.

Mr. MACKAY. Thank you. I apologize for preempting you.

Mr. NELSON. No, not at all. I think maybe some of these questions that you and I have been pondering here, we ought to be ad-

dressing them to David Stockman and Caspar Weinberger and Jim Baker.

Mr. MACKAY. Well, if you will recall, I tried to address this precise line of questions to Dr. Keyworth.

Mr. NELSON. Dr. Keyworth is another one.

Mr. MACKAY. And Dr. Keyworth said, "Our plan is to do whatever it takes to be preeminent in space," which implies that we are doing whatever it takes to stay ahead of whoever we're competing with, which means we don't ourselves have a plan. We are reacting to someone else. That was his answer.

Mr. NELSON. Well, I think we need to keep raising these questions, and you just happened to be here at the right time. [Laughter.]

Mr. MACKAY. I'm sorry about that.

Dr. LOVELACE. That's absolutely no problem, Mr. MacKay.

Mr. NELSON. I want to ask just a couple of quick little questions here. I would like to know, you sort of danced around a year ago, the question of a fifth Orbiter. Do you have any different feelings now?

Dr. LOVELACE. Well, I would have to say—and we try to state in our testimony, Mr. Nelson—that we believe we ought to maintain that option in the budget under question here. How much funds are required for that, maybe in the order of $100 million, I think serious thought should be given to that. I know we get into a lot of discussion about mission models and all of that, but I just have that feeling that we are going to be very sorry.

Mr. NELSON. You said in the order of $100 million.

Dr. LOVELACE. I don't know. You should not take my comment on that as being——

Mr. NELSON. I yield to Mr. Volkmer.

Mr. VOLKMER. I would just like, in that line, because I plan to approach this—in your statement you use a sentence on page 18, in discussing the fifth Orbiter, following along the reasons why we need to keep the options open and everything, this sentence, and I would like to know what you mean by one word: "The time for making the decisions to reflect these commitants is now."

Dr. LOVELACE. Well, I think that we predicated that——

Mr. VOLKMER. I would like you to elaborate on that.

Dr. LOVELACE. Yes. I think that is predicated, Mr. Volkmer, on the rather simple set of facts that the industrial base that is in place, which is a very complex set of arrangements with a number of companies in first, second, third tier support, as well as the tools and all of the equipments that allow you to manufacture an orbiter or assemble it by the prime contractors, it's in place now. It will not stay in place on the basis that maybe there will be another orbiter ordered, you know, 4 or 5 years from now. That would not be a very practical business decision for the companies that are involved. They simply cannot afford to do that. And then it will be very expensive, in my experience, very expensive, maybe to the point of being prohibitive, to come back and try to reassemble that team and put together additional flight hardware.

Mr. VOLKMER. I yield back to the gentleman from Florida.

Mr. NELSON. Well, I am just going to ask one quick question: Do you think we're going in the right way, Dr. Lovelace, on the commercialization of the expendables?

Dr. LOVELACE. I think that we are. I think that we ought to—let me put it this way, Mr. Nelson: We ought to let the marketplace test it and see. OK? If you're asking me will a company, you know, be successful in it, I think only the marketplace will tell that, but I think it's important in our society to let that test be made, and then we'll know absolutely after that whether in fact it was good business decisions that were being made or that have been made.

Mr. NELSON. In just my parting comment, I would say that as we pursue this vision, where we ought to be going, what should be the plan and so forth, I want to go back and I want to understand, you know, what was the vision in the early sixties when we had a commitment and the commitment was that in the manned program we were going to the Moon and return, and at the same time, concurrently, there was the thrust on the interplanetary and so forth. I want to measure as to what our plan is now or lack thereof, as to how it was then, because we had some spectacular success and America and it's society is all the better off for what we did in the sixties, so I want to keep raising that question.

Thank you, Mr. Chairman.

Mr. VOLKMER. The gentleman from Pennsylvania.

Mr. WALKER. Thank you, Mr. Chairman.

With regard to the fifth orbiter, what would be your reaction to potentially putting together a consortium of international companies or even other countries in helping us buy a fifth orbiter—perhaps putting together people out of the European space community, Japan, some people who have been looking for lift capacity—in order to bring down the purchase price that we might have to expend for a fifth orbiter.

Dr. LOVELACE. I certainly—as a concept, Mr. Walker, I haven't thought much about that. Maybe you have. But as a concept that doesn't seem unattractive. I think you would have to—the thing that pops to my mind immediately, though, is that if we are talking about inviting other nations to invest their dollars in the United States, that may be a difficult sell. OK? If we are talking about constructing a different base—some of it in Europe, let's say—to build an orbiter, that I'm afraid would be a very expensive and time-consuming process, so I'm just not sure on a business sense how that would be viewed by those countries.

Mr. WALKER. Well, and I'm not either, and I'm not certain just how they might react to it, but the fact is that when we were in Japan last year the Japanese were indicating that they wanted to have a certain amount of lift capacity from this country for their space communications satellites. It might well be that they would be willing to buy into the program, therefore. That would basically assure them of some of the space over a period of years. That might be the tradeoff.

The European Space Agency might well buy into this as an alternative to Ariane, so that they have a dual lift capacity. It just seems to me that there may be some bargaining chips that the United States has, and it would certainly bring down the cost relative to the American taxpayer and yet assure us that that fifth or-

biter that a lot of us think is necessary could come on line and be available to use for missions well into the next century.

Dr. LOVELACE. And I think that that is a thought with merit and worth exploring. The only other thought that I would have is that many times countries are interested in joint undertakings with us for other reasons. They are very interested in learning the technology, and the only way you really learn that is to do it, and so we ought to factor that in, I guess, into our decision. It could be part of the motivation of people who might want to participate in that process in order to learn from it, and then to take that technology back for other purposes.

Mr. WALKER. To some extent that leads me to my next question: How vigorous do you view the potential for commercialization of outer space, particularly low Earth orbit, that will grow up around a space station? Do you view that as something which has a potential of some dramatic impact for the next 20 years?

Dr. LOVELACE. Well, I personally think that it will have, Mr. Walker. I think the station in its own right is, as opposed to a means to an end, tending to see it as a means to an end, I see it as providing a basis for our being able to—given that we are committed and maintain the stability of really developing; for example, in the materials processing area. I have said, in fact before this committee some years ago, that I personally believe that out of all that activity will come a lot of understanding which will improve things here on Earth, things we will do differently as a result of the experimentation that we will be able to do in low Earth orbit as well as a class of things that we will continue to do in low Earth orbit in terms of manufacturing processes.

Mr. WALKER. Well, I tend to agree with you, and I guess my own vision of this thing is that there are an awful lot of other people around the world, not only within the United States, who are going to agree with that. A lot of businessmen are going to agree with that.

Now if we are the people with the space station that is capable of engendering that kind of commercial activity, that gives us a great resource which is probably the main justification for going ahead and building it, but it also assures that some of those other nations who want to commercialize and use that commercial potential, again will have to have a way of getting to that station and utilizing the facilities of that station, which brings me back to the fifth orbiter. That is something then that is salable, it seems to me, to other nations, something which they cannot necessarily get by using their own lift capacity, named Ariane.

With regard to the long-range plans of NASA that you are concerned about and I have as a concern as well, are you convinced that they are aggressively committed in their long-range vision to the commercial expansion in outer space?

Dr. LOVELACE. I think so, Mr. Walker, based on my insight into the agency. I think they are committed, and I think that—I would have to say one other thing. I think they are also committed to generating that plan that we have talked about here before, and I think that will happen. I think what we at AIAA are saying is that we want to encourage that process. I don't think that it is the case—it rarely is—that there is either totally lacking the encour-

agement to commercialize or that they are not doing any thinking and working on this long-range planning. I believe they are.

Mr. WALKER. But if I understood you correctly, in your response to Mr. MacKay with regard to a percentage of the GNP, it sounds to me as though you also want to remain somewhat flexible in all of this. It seems to me that we are going to be on a very, very great learning curve as we work and commercialize. The more people you put into space, particularly people in space on a long-term basis, the more commercial activity out there, you are going to increase your learning curve substantially, it seems to me, which is going to change your sense of commitment, your sense of balance about what kinds of money are needed in various programs, or certainly for the space program as a whole. You know, I would think that a long-range plan should not be something that, for instance, would lock this subcommittee into something that we carry out over the next 20 years kind of regardless of what comes up.

Dr. LOVELACE. Absolutely should not and in fact, as I understand the process, cannot happen. But a plan is not necessarily a contract to which all parties are committed for all time, but it is a baseline. It then tells you, you know at one point in time, you know what it was you were planning to do and thought you were going to do, and you can then test your various decisions that you have to make as you move along against that plan. It is surely the case that you will deviate from it, and should.

Mr. WALKER. You are somebody with some detailed knowledge on this, though. If we had written a plan in 1965 that predicted where we would be in 1985, would we have written a plan that would have us where we are today?

Dr. LOVELACE. I think some elements of that plan, Mr. Walker, were in fact worked out. In fact, the shuttle, we tend to think of that as a program, as an end. It was in fact the first step of a larger plan, and the space station is the next step, and having an orbiting maneuvering vehicle is also a part of that, so that plan was in fact drawn up. Because the time constant is so long that many of us, many of the people who were participants in that planning are no longer active either in the Congress or in NASA, we have to remind ourselves, go back and dust off some of those.

Mr. WALKER. But you would also say, though, as the horizon becomes bigger, the plan-writing then becomes much more difficult as well.

Dr. LOVELACE. Sure, and that was a planning activity and a very good planning activity that resulted in the shuttle. We have not such a coordinated plan across the sciences, planetary science programs, application programs, and I think that that is equally needed.

Mr. WALKER. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you.

Just to mention one other thing to you, Dr. Lovelace, when the AIAA goes into its development of a long-range plan or proposal, I would just like to let you know that I know the members here and I know the staff would be more than willing to work with you on that, because we too would like to see something done in that regard. I realize, I think, a little bit about when you develop that, you don't necessarily mean that that's the way it's going to develop

because we learn from things that happen in between. From the time we start until the time we are supposed to end, we have learned and that changes whatever we are doing as we learn. Is that correct?

Dr. LOVELACE. That's absolutely correct, Mr. Volkmer, and I would say that we welcome the offer to work with you and with your committee and staff as we work our way through this. It is clear that that will only be a point of departure and it will change.

Mr. VOLKMER. Well, just to bring that out, we can take the shuttle infrared telescope facility. As you have mentioned in here, there are no funds for it, and the first word to that—"shuttle"—is no longer going to be part of it because it's not going to be on the shuttle, because we learned from IRAS just last year that we can do the cryogenics, the cooling, for a long period of time, so we can possibly make a free-flyer out of it or use it on a platform. But now the latest I just learned is—and this shows how things get put back—is that of course to go to a free-flyer we are going to have to go back and start a little bit over as far as development is concerned, but then by the time we get through that we may find that, hey, we can just put that on a space station.

Dr. LOVELACE. That's progress, although it doesn't seem like it at times, but it is progress.

Mr. VOLKMER. Then by the time we get ready for the free-flyer, we may say no, we are going to change it around; we are going to put it on a space station instead as part of the platform—just a comment on our long-range plan, to use it as an example.

We have already touched some points. I would like to go over, I quite agree with you on the planetary exploration and physics and astronomy and on research and analysis, that we need to look at that very closely. Yesterday we commented on that with Dr. Edelson, and I have asked him to furnish us exactly how much this amounts to, and as far as the university level also and also for equipment, or looking at that $11 million that should be in there for equipment and instrumentation, because some of us feel that that's a necessary ingredient. That is the type of thing too, I think, that should be in any long-range plan as to what we are going to do, being able to provide the university level, with being able to utilize the data or even use the data or go forward with basic research in the future, if we don't have sufficient funds in the budget.

And then we get into the ACTS program, where you support the continuation of the flight testing. Then when I get into those too, you know, I come up with a little problem and I would like to ask you a question: Now that we have added $105 or $120 million to it, where do I cut it out? Do I take the space station money and say, "Forget that for a while," and we'll go put it over here?

Dr. LOVELACE. Well, let me——

Mr. VOLKMER. Knowing the problems—and you've been through it—knowing the problems we have, and you haven't had it this bad—I mean, when you were there you didn't have the $200 billion deficits and the problems with that.

Dr. LOVELACE. That's true. I can't take credit for those. I left before we got to that level, anyway. I may have contributed to that.

I think what you do—let me make a couple of observations—I think what you do is, having decided that ACTS or the space station or whatever is a credible goal and that Congress wants to proceed on that, and understanding what the cost is—for example, the cost of the ACTS program, which was, I think, totaled out at $354 million—then you look at the funding profile of those programs. In fact, the funding profile of the ACTS program has already changed and gone down. Maybe that's the good news of the delay, but you need to then look at the funding profile. This is what one, I think, normally does if you feel that your budgets—and they are—are constrained, you know, and cannot just be expanded.

I would only make one other observation relative to the space station, and that is that it is very important in the initial undertaking of a project or a program like that to sufficiently fund that thing, because it is in those early days of concept formulation and design, layout, that you make or break your problems for the future. And we many times, because of the very constraints that you and I are talking about, tend to reduce that and sometimes reduce it too much, such that we don't do a very thorough and iterative job in the very front end of the preliminary design of, in this case, the space station.

I would personally be very leery of reducing that, in other words, looking to that program for funds to support other activities, but I would tend to look at some of the other programs and see whether the funding profiles might be modified. The price you pay for delaying things is generally the matter of inflation, which let's hope will stay reasonable for a few years.

Mr. VOLKMER. Yes. We've just got a little money in there, I think about $3 million or so, for AXAF, and we don't want to take that out. Surely we don't want to take out the gamma ray observatory or the Mars climatology. You understand our predicament.

Dr. LOVELACE. It is difficult. You have a very difficult problem and we are fully appreciative of that.

Mr. VOLKMER. It was a lot easier, I think, in the earlier days when we just said, "Well, these are all good, and let's just add a few and we'll go on from here."

Dr. LOVELACE. That's right.

Mr. VOLKMER. Today adding a few is not as easy as it used to be.

I don't have—I think we've covered everything else through the other members on the other areas that I had questions on. Just a moment. Let me just make sure.

One other area here: I would like to get back to space communications, something we haven't discussed but it has been proposed as a possible idea. What would be the possibility, and let's get into the communications area, of a joint consortium—we have Comsat, we have RCA, AT&T, on down the line of providers, and then we also have people in the user community—of a joint consortium for research and development in communications?

Dr. LOVELACE. Well, the thought has, in fact, been explored in other areas, and it may be that the—I will just think out loud about it a moment—it may be that the current climate, if one thinks about concerns about antitrust activities——

Mr. VOLKMER. Let me eliminate it. Let's assume that we had legislation that would permit that.

Dr. LOVELACE. Let's assume—and that climate seems as if it may be a little more permissive for cooperation, not permissive to antitrust—but if that be the case then there might be some charm in that. I think that you would have to probably still consider, certainly in the early phases, some Government funding to get the thing really rolling along. What those industries—since I really do not represent, personally represent that industry—what their thoughts might be on that I really couldn't speculate. Probably——

Mr. VOLKMER. Well, we are seeing this type of research, let's say development, within the community of manufacturing, like in semiconductors and computers. Looking at it, then——

Dr. LOVELACE. Sure.

Mr. VOLKMER.—I'm just saying that communications isn't that much different, and in the areas where some of us feel that there is challenge from overseas, the private sector should have something to do with it also.

Dr. LOVELACE. Yes, I think that's a fair observation. Maybe I didn't make my point clear. I think that getting industries together in this country to cooperate, to meet international technical challenges or whatever, is a useful thing to do. In order to make the competition at all fair, in my judgment, you are probably going to have to have substantial U.S. Government involvement, and that is the code word for funding, because we find many of our companies are not competing against other companies. They are competing against other countries, as this committee well knows, and so if even under the best of circumstances they could get together under and environment that allowed them to cooperate, they might still be very hard-pressed, even if they put all their resources into it, to muster a sufficient effort to really sustain themselves as a leader in their particular area.

Mr. VOLKMER. I have no further questions, so I want to thank both of you, Dr. Lovelace and Dr. Rohrbaugh, for being here today.

The subcommittee will stand adjourned until 9:30 tomorrow morning.

[Whereupon, at 12:20 p.m., the subcommittee recessed, to reconvene at 9:30 a.m., on Thursday, February 9, 1984, in room 2325, Rayburn House Office Building.]

1985 NASA AUTHORIZATION

THURSDAY, FEBRUARY 9, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:30 a.m., in room 2325, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Present: Representatives Volkmer, Nelson, Hall, and Walker.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order. Today we continue our review of NASA's fiscal year 1985 budget request, the third session on the space science and applications budget.

Our witnesses are: Dr. Paul J. Coleman, Jr., president of the Universities Space Research Association; Dr. John A. Eddy, chairman of the committee for the international geosphere/biosphere program, National Academy of Sciences; and Dr. Peter M. Banks, chairman of NASA's task force on scientific uses of the space station.

As I understand it, Dr. Coleman will address the relationship between NASA's program and universities. Dr. Eddy will discuss how NASA can contribute to the international geosphere/biosphere program. And, finally, Dr. Banks will describe one of NASA's efforts to insure that the space station is useful and available to the science community.

We shall start with both Dr. Coleman and Dr. Banks as a panel. And I will appreciate both of them coming up to the table.

Dr. Coleman and Dr. Banks, your statements will be made a part of the record. You may review them in full or you may summarize, however you so desire. And we welcome you here today. And we will begin with Dr. Coleman.

STATEMENT OF DR. PAUL J. COLEMAN, JR., PRESIDENT, UNIVERSITIES SPACE RESEARCH ASSOCIATION, ACCOMPANIED BY PETER M. BANKS, CHAIRMAN, NASA TASK FORCE ON SCIENTIFIC USES OF THE SPACE STATION

Dr. COLEMAN. Thank you, Mr. Chairman. I am grateful for the opportunity to discuss with you the budget proposed for space science and applications in fiscal 1985. I am especially pleased to participate in discussions that concern important new directions in the Nation's space program. In particular, I am delighted to see the space station initiative, starts for the Mars geoscience/climatology

orbiter and upper atmosphere research satellite, as well as an overall increase of 18 percent in NASA's R&D budget.

In my examination of the budget, I looked for continuity and balance in the program concerned with research and development. In my preliminary remarks today I would like to discuss some of the items that I feel could profit from additional support and, in addition, some areas of NASA's management that could, I think, be modified at essentially little cost to improve the way in which we do business in R&D.

I would like to first discuss the space station component of science and applications. I am very much encouraged by NASA's initial steps in their approach to the space station design. They have had many in-depth discussions with potential users. They have stated the intention, in fact, to use computer jargon to make the space station a user friendly system. They have solicited input especially from the scientific community. And Dr. Banks is chairing a group that will be concerned with that.

I think the issues are especially things such as flexibility, the cost of doing business on the space station, and I will discuss some of the history of why I am concerned about this that is associated with the space shuttle, and the long-term objectives, whether, in fact, we intend the space station to be something that will be essentially or primarily an on-orbit research platform or whether it is going to be a jumping off point for more extensive activities in the solar system. All of these things will affect the design and should be considered early in the program.

I have taken it, and I believe it is an imperative of the space station initiative, that we begin immediately to develop the scientific and technological bases that will allow us fully to exploit the capabilities of the space station on orbit.

I am very much concerned about three areas that I think are especially relevant to the space station: Life sciences; materials processing, or what is now called microgravity science and applications; and remote sensing.

In anticipation of a permanent human presence in space, we really need to move now to strengthen the relevant components of the research and development. We need more intensive programs concerned with longer term effects of exposure. As you know, there is a very substantial effort now concerned with the effects of shorter duration space flight because of their impact on the space shuttle productivity, if you will. But even the extended space shuttle programs that are being discussed right now, missions only as long as 20 days, will add significantly to the complexity of the ability that essentially will push our knowledge of what man can routinely put up with in that environment. As we go to the durations that are under consideration for the space station, it is all the more important that we increase our activities in understanding the effects of zero gravity as well as other things, such as how people perform in groups for extended periods of time in an environment like the space station, how we can effectively shield them against radiation for longer periods of time, and development of the life support technology that is going to be needed.

I would like to also comment that I think the challenges to researchers in life sciences that are associated with the requirements

of the space station are such that we will over the longer term strengthen the program and essentially strengthen the discipline in life sciences. That is, the work that will be done and supported as a part of the natural evolution toward the space station will encourage some of the best people to go into life sciences and will, in general, strengthen that discipline overall, as does essentially all of the NASA-supported R&D, working in its own specialty, develop the strengths of the disciplines themselves through the education of the graduate students and the people who may do their research on space-related projects and then go on to other areas in their disciplines.

Over the nearer term, we need to increase the activities in the life sciences as a component of the space shuttle program. We need to do the work that's going to develop the baseline data for space station. As you know, the on-orbit part of the program, the experimental part of the program, is growing, and those are essentially the only components that truly validate the scientific developments and theories that are worked on in the laboratories on the ground. So we need to provide the additional strength in the basic science component and the advanced development component of life sciences in order to make the best use of the shuttle space and time that's available to the life sciences program.

I recommend in order to do that that NASA augment the budget for life sciences by $5 million. I think that would be an appropriate component associated with the space station initiative.

I would like to discuss now materials processing in space. I think the research and the advanced technological development in this program, as in others, should lead the design of the space-based equipment facilities that we're talking about in the space station. The program that's identified in NASA's budget as materials processing in space is now organized within a division that is called Microgravity Science and Applications Division.

The recent successful MSA projects on the space shuttle include experiments in bioseparations, about which there has been considerable discussion; crystal growth; and precision production of latex spheres. In 1984 NASA plans to carry out some 15 experiments, MSA experiments, in space. As we sit here now, there are three such experiments in this program in operation on the mid-deck of the *Challenger.*

I think the progress in MSA has been substantial and encouraging. There is a pressing need to develop and fund more flight experiments for the shuttle so that we can establish the research parameters that will be needed for space station facilities; that is, we need to do the research and the advanced development now to maximize our ability to use the space station.

I find growing interest in the university community, many more excellent experiments being proposed. There are scientists and programs in other agencies now; among them, people at Los Alamos National Labs, where I have some responsibilities, who are beginning to look to possibilities of research in materials processing in space.

Also, as you are fully aware, there are commercial and industrial overtones here in the space station. Really one of the essential components, I think, of the proposal is the view that the United

States will lead in the commercialization and industrialization of space. I think just the other day another agreement was reached with an industrial concern on some work. I think it was the 3M Co. this time. I don't know any of the details. But I think it's a measure of the growth of interest in this activity, and I think the basic research in the MSA program is an essential step in this direction.

If I look forward then to the space station program to be consistent, I think that many of the ongoing MSA programs are being slowed too drastically because of funding constraints. In 1983 the budget was $22 million. In 1984 it was $23.6 million. And there were the augmentations that, of course, the Congress was very much involved.

I think, to be consistent with the initiative of the space station and a reasonable pace of growth, we need to increase the funding for the program by $10 million in fiscal 1985.

Another important element, in my judgment, related to space station, involves studies of the Earth from orbit. From this perspective we derive the data sets that give us the global view of phenomena on the Earth. Among the most recent important developments are the shuttle imaging, the results from the shuttle imaging radar and the multispectral infrared scanner. I think these are programs of the type that show how much more potential there is yet unrealized in the remote sensing program.

Financial support for land-related remote sensing in the NASA program has been cut really dramatically over the last few years, and I think that we have now come to the situation in which the program has been cut to the bone and yet it's clear that the interest is growing and the need is increasing.

There is a commercial aspect here, as you are fully aware. The Japanese and the French and the Soviet Union, as I understand it, also are now moving to commercialize programs in these areas, and we need to continue to lead the way in this field, especially as we look toward permanent presence in space on the shuttle and space station.

I would like to make some general remarks about the space station. I think the case has been well made that NASA should work to satisfy the broadest national needs for space science and technology, including the needs of the civil and commercial, industrial, and national security sectors. The model for this broader scale program, I think, is the one that NASA has evolved over the years in aeronautics. A cornerstone of NASA's program in aeronautics is the facilities that are available at centers like NASA-Langley and NASA-Ames. I think the space shuttle offers, by analogy, a similar set of facilities on orbit, and the space station heralds a new era in the availability of on-orbit facilities.

As you are probably aware, a group of industrialists convened by President Reagan has told him that the commitment to the space station would be the single most important factor stimulating space commercialization. I think this, in combination with an important aspect of the fact that NASA is now maturing as an agency so that people are beginning to retire and slots are becoming available for younger people to come into the program, offers a very exciting possibility. My feeling is that with the magnet of the space station and the availability of positions in the agency, they

are not only going to have an opportunity to hire young people and bring them into the program, but they are going to have an opportunity to get the best.

As you know also, NASA is well along in the development of a program to fly nonastronaut observers. I think that's another important component of looking forward to the space station, the idea that the space station will be useful to a broad cross-section of people who don't necessarily have to devote a significant fraction of their professional careers to get on board and do something technical or industrial or commercial in the platform.

All these elements are coming together in a way that I think really suggests that the next 10 years in space is going to be not just evolutionary but revolutionary.

I would like to now turn to a couple of programs that are basic to the university research and analysis efforts; that is, they are very much the backbone of support of the graduate student-based research programs at universities.

One of them is the planetary program. The Congress has been very active in insuring the continuity of support in the planetary program. It appears to me that this budget for 1985 reflects an unwillingness to accept the intent of the Congress to maintain that continuity. In going through the numbers, I find that in the planetary program, especially as it stands now with the 1985 budget, there will be a cut that would be very significant, that would undo a lot of the things that have been maintained and, in fact, strengthened in the program.

In going through that analysis, I have concluded that the planetary R&A program and advanced technological development should be increased by about $13 million in order to maintain what I see as the trend that has been established in the course of the last couple of years.

Another element of the program that is very much university based is the space physics program, which is part of the applications side of the Office of Space Science and Applications, even though in every respect it's a basic science rather than an applied science. I am very much concerned about the long-term effects of our, shall I say, vacillation in international relations. There is a program in that office which began its life as the OPEN program, which was a study of the plasmas in the Earth's neighborhood. In the course of the discussions at the economic summit in Williamsburg, this program was identified as one that had especially high potential for international collaboration. Subsequently, with that impetus—and I should add that it had been viewed as an international program even before that—but with the impetus of the Williamsburg economic summit and that recommendation, the program became a very much more intimate and specific international collaboration, to the extent now that in the negotiation process specific tasks are being hammered out for the different nations involved; that is, the member nations of ESA and the Japanese and ourselves.

My concern is in looking at the 1985 budget that there is not the support for us to do our part of the work. We are essentially—I am sure it's not written down or signed yet or whatever, but the expectations are there, I am firmly convinced, among our international

collaborators in this program, that we will do our part of it. I think the money is not there to do a proper job unless we take a whack out of the R&A; that is, the basic research component of the program.

So I would recommend that $6 million be added to the fiscal year 1985 budget for this program, which is now called the international solar terrestrial physics program.

I would like to turn now to the first of a number of things that have to do with the way we do business in the basic research and development component of the NASA program, especially the university-based component.

I think that one of the objectives in all of this is to strengthen the R&D community in this country. NASA's job is to strengthen the R&D component that is space-related. The university-based part of all this is very important both in the general R&D community and in the space-related R&D community.

There is a great need in the universities for university-based research has deteriorated over the years, for a number of reasons, many of which have to do with the way funds are budgeted and the rules under which the funds are spent. I won't go into the details of that. There are some of them in my prepared statement.

Let me just say that this need has been recognized widely, and it's well documented. I think a measure of the need is the experience that the Department of Defense had when they set up a special program to do something about the capital equipment base at the universities. As I recall, they made available $30 million, and the response from the universities, knowing full well that there was only $30 million, was some $800 million; that is, the proposals, the requests totaled $800 million. That program was one that came up rather quickly. I don't think the grapevine and the notifications were nearly as well—a lot of people didn't know about the program, and yet there was that kind of response. I expect this year it's going to be a lot bigger.

What I am trying to say is that the Science Foundation has recognized the need. The Department of Defense has recognized the need. The NASA-sponsored part of the R&D community has similar needs. I think it may be essential that we handle it in a similar way, that we try to set up a specially targeted fund for this. A group who has recommended $11 million, and I think, based on my feeling for the dimensions of the problem in the community involved, that's a reasonable number. I would recommend that that money be added to the budget.

I mentioned capital equipment. There are a number of what I would consider management and policy issues that can be dealt with. The rest of these are items that I don't think would require any budgetary augmentation and I think in fact might make us more efficient, more effective and, in so many words, get us more bang for the buck.

A lot of these things have to do with the fiscal policy, the fiscal management. Others have to do with administrative items, and others have to do with the technical infrastructure of the university R&D community.

The overriding need in the space program, space-related R&D, is access to space flight. We have—it's the lifeblood of the kind of re-

search that we do. There is a problem in the tremendous growth of cost of doing R&D. A lot of our budgets, as you know, overall for R&D, the university-sponsored part of it, have probably in real buying power dropped 50 percent over the last 10 years at the same time we are faced with costs on the campuses, as are people in other components, that increase faster than inflation.

The cost of equipment is increasing because the flights are more complex. and the problem has been, I think, exacerbated by the situation on the space shuttle. We, those of us who were involved early on in the discussions of the space shuttle, were convinced that it would be an opportunity to fly what we then called "laboratory-quality" equipment, and we would be able to put gear up into space and do experiments and live with failures and if they didn't work, fly them again and that sort of thing, on a short time schedule.

It hasn't turned out that way. Basically, we do the same kind of quality control and so on that we do in the unmanned program, so that the net result has been that R&D on the space shuttle is a very expensive and time-consuming thing and has not come close to fulfilling our expectations for providing quick turnaround in the kinds of programs in space science that we had on the rockets and balloons, which is a good analogy. We looked to the shuttle as a way to get into space in much the same way that we do now at using balloons and rockets as a test platform.

There are steps in the right direction. NASA is, I think, aware of this, and they have two programs, the Spartan and the Hitchhiker, which are intended to provide this kind of thing, intended to respond to this criticism.

I just would urge that the pressure be kept on and that they renew their efforts to do something about this. I especially raise the point now because we are starting down the road to space station, and we in the scientific community are frightened to death that the same kind of thing could happen.

Another component of importance is access to major facilities, facilities such as large-scale computing. The computer, as you know, is the tool that crosses all disciplinary lines. Everyone in every walk of scientific life is very much involved in the uses of computers. Large-scale computers are becoming more and more important as we develop our abilities to do theoretical modeling, and also as we strive for ways to handle more efficiently the data that we bring back from space. We need networks for access to large-scale computational facilities. We need the computational facilities as well, but I think there is progress in that direction. What we are lacking now is an effective way, an effective program, to build up that infrastructure.

NASA has taken a step in the right direction in setting up an office to concentrate on this in OSSA, and I think it is a step in the right direction. But it is something that I would like you folks to keep in mind to be conscious of so that we can be sure that management maintains the priority for that sort of thing.

I have singled out computers because they are so important to such a broad range of disciplines. But there are other large-scale facilities of the same type, facilities to which people need access

just the way the aeronautical designers need access to the wind tunnels and things.

There is a lot of discussion about the Federal role in R&D. Where the financing of R&D by the Federal Government should stop and where we would expect private industry or other sectors to pick it up. The words that are said which essentially define the Federal Government's role as funding the long-term high-risk R&D certainly provide a reasonable description of the things that ought to be done. The problem is in the interpretation. There is, it turns out, a great range of interpretations possible.

We have been thrashing around with this in recent years. I am not suggesting that we shouldn't be. But what I am suggesting is that as we do this, we remember that we don't know—this R&D establishment that we have is still, despite its troubles, the best in the world—we don't know exactly how we got there, and we need to be very careful about the rate at which we try to effect changes in these things.

So as we consider how and in what way the Federal portion of R&D should be carried and the magnitude to which they should contribute compared to other sectors, we need to realize that whatever we decide to do has to be implemented smoothly and continuously.

There is another component of the NASA program with which I am very much concerned and in which I am very much interested, and that is what NASA calls technology utilization. Some folks call it technology transfer. In my work at Los Alamos, I manage programs that involve applications as well as basic research. Because of that, I have become familiar with things that I think are closer to being ready to move into the commercial sector. I have been puzzled as to why things don't work better. I don't know the answer yet. I think that despite the fact we don't understand the formula, we are making it work better. I would like to encourage our continuing to work hard to do that.

NASA has budgeted $9.5 million for their part of that program. My personal feeling is the program is a little bit too passive, in the sense that it is basically dissemination of data, holding some workshops and running these information centers. I would like to see a more active or aggressive role in that activity, to the extent that the charter and the laws will allow it.

There are many other items of this type that affect us. I am concerned, as many of us are, I am sure, about the effect of the limitations on sole-source awards that are being considered by the Congress right now. There is, to the best of my ability to read through all of the material, very little specific treatment for the university portion of the R&D establishment. That could cause additional complexities of the type that we are talking about, things that cost money and take time and effort, that really aren't necessary.

There is also the fiscal year boundary problem. Early on in the NASA program, we had what was called step funding and we were able to do two things with that. One is cushion the blow if there were a cutoff in funding in any particular program and spread it out with a gradual decrease over a couple of years. The other is, deal with the fiscal year boundary problems where sometimes we go 3 to 6 months without any funding from any source and still we

have to make the payroll and things of that sort. It's a cash flow problem, which is the toughest thing in any business, and it's no different in ours.

There are accountability requirements that are very awkward for us to deal with, wherein we might have two or three grants in a research group and we have to account for every dollar of every person on each grant, and we can't move them back and forth, and so on. It's a very difficult thing to work with in the university. There are others, but I am sure you are aware of many of them, in fact most of them.

So, Mr. Chairman, I very much appreciate your time and thank you for your attention.

[The prepared statement, plus answers to additional questions asked of Dr. Coleman follow:]

Prepared Statement of Paul J. Coleman, Jr., President, University Space Research Association

Professor Paul J. Coleman, Jr.

Paul J. Coleman, Jr., is professor of geophysics and space physics at the University of California at Los Angeles (UCLA) and an assistant director of the university's Los Alamos National Laboratory in New Mexico. At Los Alamos, he manages the Earth and Space Sciences Division and directs a branch of the university's Institute of Geophysics and Planetary Physics (IGPP).

Professor Coleman is president of the Universities Space Research Association (USRA), a consortium of universities chartered by the National Academy of Sciences to foster space-related research, technological development, and education. There are fifty-four universities in the association.

Dr. Coleman has devoted the major part of his professional life to activities concerned with the nation's space program; first, in industry at the Ramo Woolridge Corp. (now TRW); next, in government service at the headquarters of the NASA; and thereafter with the University of California at the Los Angeles campus and the Los Alamos National Laboratory.

Dr. Coleman's research in the space sciences began with his work on Pioneer 1 and extends to his current collaboration on preparations for Galileo. In between, he participated in a number of Mariner and Pioneer planetary missions, as well as Apollos 15 and 16, and the Explorer, Orbiting Geophysical Observatory, and the Applications Technology Satellite series of earth orbiting missions.

INTRODUCTION

Mr. Chairman, members of the Subcommitte, I am grateful for this opportunity to discuss with you the budget proposed for space science and applications for FY 85. I am especially pleased to participate in discussions that concern important, new directions in the nation's space program. In particular, I am delighted to see the Space Station initiative, starts for the Mars Geoscience/Climatology Orbiter and the Upper Atmosphere Research Satellite, and an overall increase of 18% in research and development (R&D). Nevertheless, I believe the proposed budget contains some deficiencies in NASA's support of R&D at universities, and some inconsistencies with regard to the development of the scientific and technological bases that will allow us fully to exploit the capabilities of the Space Station.

Three areas that have deficient or non-existent funding in the proposed budget are:

Planetary Sciences Research and Analysis
Recommended augmentation $13M

University Capital Equipment
Recommended initial funding $11M

Space Physics Research and Analysis
Recommended augmentation $6M

Three areas that have deficient funding and are relevant to the effective utilization of the Space Station are:

Life Sciences Research and Analysis
Recommended augmentation $5M

Materials Processing in Space Research and Analysis
Recommended augmentation $10M

Land-Related Remote Sensing Research and Analysis
Recommended augmentation $10M

In the sections that follow, I will discuss these items in more detail. Also, I will address some elements of policy and management that affect the efficiency of NASA's university based R&D effort.

SUPPORT OF R&D AT UNIVERSITIES

In my examination of the President's space science and applications budget for NASA, I have taken as axiomatic the following statements:

> It is vital to the United States that the nation's research and development (R&D) effort be strengthened.
>
> The National Aeronautics and Space Administration (NASA) is the designated custodian of an important part of this R&D enterprise. More specifically, the NASA is chartered to foster the nation's leadership in the space and aeronautical sciences and technologies and their applications.
>
> An essential component of the R&D effort of the U.S. is that based at the nation's universities, where R&D and the education of future scientists and engineers are performed in combination.

As you know, historically about 3% of the NASA expenditures has gone to universities. As you are aware also, the purchasing power of this fraction of the NASA expenditures has, in the past ten years alone, decreased by almost 50%.

This total includes money that passes through the university. In particular, when a university principal investigator (PI) for a NASA spacecraft contracts with an industrial concern to fabricate a flight-quality instrument to the specifications of the PI, the cost of that instrument is covered by the university from the PI's grant or contract funds. Thus, the money passes through the PI's home university to industry, although it is properly carried on NASA's books as an allocation to the PI's university.

Because flight quality instruments on today's complex spacecraft more often than not cost well over a million dollars, often several million dollars, the pass-through component is a significant and growing part of the 3% just mentioned. Other factors that have increased the financial pressure on the university R&D community include faster-than-inflation increases in the costs of fringe benefits and campus overhead.

The decrease in the real level of support and the simultaneous increase in the real cost of doing R&D has greatly weakened this enterprise. Only recently, with increases in federal support, have we been able to begin the needed rebuilding process. In the course of this process, we must strive for

continuity and balance. Thus, over the longer term, we must both obtain results from our R&D programs and insure the future strength of the effort. Toward this latter objective, we must attract and retain high quality faculty, attract the best students, and train them thoroughly. To accomplish these goals, we need solid financial support, modern facilities, and challenging research projects.

Balance and continuity are important attributes of any long-term R&D program. However, they are vital attributes of any university-based R&D program, because of the component of this work that represents graduate student research towards advanced degrees. A typical graduate student in the physical sciences spends between five and six years from his or her entrance into graduate school to the completion of the requirements for a Ph.D. A period of upwards of ten years may be required to assemble, equip, and bring into full productivity a strong research group. Thus, in their respective searches for challenging research, both faculty and students have longer term perspectives.

The Research and Analysis (R&A) component of NASA's expenditures supports the basic research and advanced technological development that is the backbone of the space science and applications program of NASA. Therefore, it is simultaneously the foundation of the space-related graduate-student programs at the universities.

In view of the accumulated needs of university research, I am disappointed that the administration has requested an increase of only 1.7% in R&A.

I would turn next to my specific concerns and recommendations in the areas of planetary science, university capital equipment, and space physics.

Planetary Sciences Research and Analysis
Recommended Augmentation $13M

This augmentation is for basic planetary research, much of which is carried out in universities. As mentioned previously, continuous funding is crucially important in the university environment, where most of the funds support graduate student-research. The planetary program has suffered greatly from fluctuations in funding. This year, the administration's request is $5M less ($7.4M less, assuming a 4% inflation rate) than the amount appropriated by Congress last year.

We recommend an augmentation of $13M, which would raise the level of funding for the Planetary Research and Analysis programs to a level not quite equal to that of FY 81. This augmentation would provide for continued analysis of Pioneer and Venus and Voyager data, instrument development needed for the Mars Geochemical/Climatology Orbiter mission and for a future comet rendezvous mission, scientific support for U.S. investigators who participate in international solar-system exploration flight programs managed by other countries, continued development of the technology for the Mariner Mark II spacecraft, modest upgrading of some laboratory capabilities, and continued support for low-cost experiments on current flight opportunities for which there is no current source of support.

University Capital Equipment: A New Component of Research and Analysis
Recommended Initial Funding $11M

In their initial report entitled The Universities and NASA Space Sciences, dated July 1983, the NASA/University Relations Study Group (Ref. 1) recommended that, beginning with FY 85, the NASA budget $11M annually for the capital equipment (laboratory instruments and computational equipment) needed to bring the space science facilities of the nation's universities up to modern standards.

I am disappointed to be unable to find any funds for this purpose in the proposed FY 85 budget. The reality of the need is well documented and widely accepted. Indeed, the DOD and the NSF have specially identified funds for this purpose. The NASA-sponsored components of the university-based R&D community should be similarly updated.

I will not reproduce here the details of the justifica-tification for the proposal of the NASA study group. However, I wish to endorse them.

I mentioned earlier the overall, long-term shrinkage in NASA's support of university R&D and the exacerbating factors associated with the higher costs of more complex spacecraft instruments, faster-than-inflation increases in fringe benefit costs and university overhead, etc.

In addition to these fiscal pressures opposing the prudent allocation of funds for capital equipment, there are specific constraints in the NASA procurement policy that have helped lead to the current unfortunate state of affairs:

(1) Contracts let to universities for the design and production of space flight hardware generally exclude the acquisition of capital equipment.

(2) Grants to universities from the NASA funds for R&D require special processing of requests for capital equipment, although in principle they provide for same. However, in addition to all of the fiscal pressures cited above, there is the cash flow problem. Thus, for a grant of $60,000 per year typical of an R&D grant in the planetary program, a $100,000 mini-computer requires a one-time annual budget increment of 166%.

(3) Until last year, the cost of money was not an allowable charge against an R&D grant, so the usual approach to cash-flow management, spreading the capital equipment cost over several years, was not available to the university researcher.

We have been working to develop ways to handle this cash-flow problem through conventional (commercial) financial instruments. (A position paper on this matter is offered as an appendix hereto.) I am optimistic that solutions of this type can and will be developed. If they are, then we can also leverage the funds set aside for capital equipment and increase the rate at which we modernize our facilities.

In any case, I am convinced that a specially protected fund for this purpose is essential, at least over the short term. We must simultaneously work to eliminate this inadequacy and ensure that it does not develop again.

Accordingly, I recommend that the $11M annually that was proposed for this purpose be added to the NASA budget.

Space Physics Research and Analysis
Recommended Augmentation $6M

As you are aware, space flight opportunities constitute the essence of space research at universities. In solar terrestrial physics, an important space flight opportunity, now in planning, is the International Solar Terrestrial Physics Program (ISTP). You may recall that this proposed program originated as the OPEN (Origin of Plasmas in the Earth's Neighborhood) program.

However, last year it was included in the recommendation of the Williamsburg Economic summit as a program with considerable potential for international cooperation. Even before the summit conference, the program was considered as the centerpiece of a multi-spacecraft international program. However, with the impetus of the recommendation from the conference, and the pressure on the OSSA funds, the project has evolved into a much more specific and intimate collaboration with other countries, Japan and member nations of the European Space Agency.

As I stated in the foregoing, I believe that the ISTP is an important opportunity in an important area of space science, and I am convinced that it merits a start next year. Furthermore, the progress in negotiations with our international partners has been substantial and their expectations concerning our role has grown apace. It is therefore important that the funds be available in FY 85 for the advanced development work needed for ISTP, while the remainder of the R&A program in solar terrestrial physics continues as proposed. Accordingly, I recommend an augmentation of $6M for this purpose.

SPACE STATION SCIENCE AND APPLICATIONS

In my examination of the President's budget for NASA, I have also taken the following statement as axiomatic:

> An imperative of the Space Station initiative is that we begin immediately to develop the scientific and technological bases that will allow us fully to exploit the capabilities of the Space Station on orbit.

My specific concerns and recommendations in this area are as follows:

Life Sciences Research and Analysis
Recommended Augmentation $5M

In anticipation of a permanent human presence in space, we should move now to strengthen the relevant components of research and development. More intensive programs concerned with the longer-term effects of exposure to zero gravity, life-support technology, behavior in the space-station environment, and the exposure to ionizing radiation are needed.

A recent report on the mission of NASA by the NASA Advisory Council (Ref. 2) contains the following comments on the effects of zero gravity on humans.

> "Major changes occur in the cardiovascular system and in bone and muscle with long-duration exposure to zero gravity. Additional hematological, immunological, endocrine, and other changes may emerge with further studies. Some may be transient, but others may impair efficiency and may even be life threatening. The development of effective countermeasures for most of the disturbances appears, in principle, feasible, but it should be noted that this type of research characteristically requires iterative studies over many years to reach fruition. Basic research supported by the Agency has provided a basis for the effort and will continue to be an essential component. But, if the Nation is not to be constrained by health considerations in exploration of space by manned vehicles well into the 21st century, it is essential that a major program on countermeasures be initiated now. As a measure of the effort required, note that in earth-bound medicine for conditions whose pathophysiology is better known at the start than is the case in zero gravity, development of a single new drug may cost an average of about $50 to $100 million."

In view of the new start for the Space Station and the dimensions of the problems just described, I believe that there should be an increased emphasis on research in the life sciences, especially the effects of long-duration space flight on human physiology.

I would add that the challenges to researchers in the life sciences that are associated with the requirements of the Space Station, i.e., the challenges associated with the permanent presence of humans in space, is likely to attract outstanding faculty and students to the program. Thus, over the longer term, a strong program in space related life sciences will strengthen the life and health sciences generally.

Over the nearer term, an increase in the research and analysis item is called for to ensure the scientific base that is consistent with the expanded program of flight experiments on the Shuttle. The flight program provides the only means for the proper validation of the solutions provided through research and development, so we must invest as necessary to ensure that we make the best use of flight opportunities as we work towards a permanent presence in space.

The budget submitted by NASA for Life Sciences Research and Analysis provides for an increase of only $1.2M. I recommend an increase of $5.0M as an appropriate component of the Space Station initiative.

Materials Processing in Space
Recommended Augmentation, $10M

The program identified in NASA's budget request as Materials Processing in Space is now organized within the Microgravity Science and Application Division (MSAD) at NASA and involves basic research in physics and chemistry, including combustion processes, as well as materials science, including biological materials. Thus, Microgravity Science and Applications (MSA) is another program that is especially important if we are to be in a position to exploit the Space Station.

Recent successful MSA projects on the Space Shuttle include experiments in bio-separations, crystal growth, and the precision production of latex spheres. In 1984, NASA plans to carry out some fifteen MSA experiments in space. As we gather here, there are three experiments in operation on the mid-deck of the Challenger. One is a follow-up flight of the Monodisperse Latex Reactor to produce latex spheres in quantity for use by the

National Bureau of Standards. Another is a test flight of the Acoustic Containerless Experiment System, which is designed to use sound waves to hold a sample while it is being heated and cooled, so as to avoid contamination by the furnace walls during processing. The third is the Isoelectric Focusing Experiment, which is designed to test isoelectric focusing as a process for the separation of biological materials. Some of these developments were discussed in the hearings of this subcommittee last September. (Ref. 3.)

This progress is substantial and encouraging, and there is a pressing need to develop and fund more flight experiments for the Shuttle so that research parameters can be better defined as Space Station facilities are being developed. We find growing interest in these areas among the members of the university community, and many more excellent experiments are being proposed.

Also, as you are aware, there are commercial and industrial overtones here. Thus, the Space Station has been proposed with a vision of U.S. leadership in the commercialization and industrialization of space. The basic research supported through the MSA program is an essential step in this direction.

Looking forward to the Space Station, I believe that many important on-going MSA programs are being slowed too drastically because of funding constraints. In FY 83, the budget for the program was $22M and in FY 84 it was $23.6M. Since FY 83, there has been a $2.0M augmentation authorized by Congress for the establishment of university centers of excellence in bio-separation processes; an internal reprogramming of $3.0M to accelerate development of small experiment hardware and associated research and analysis activities in areas such as pharmaceuticals, thin-film crystallization, spherical shells and blood storage; and a $0.9M internal reprogramming to include the Physics and Chemistry Experiments in Space (PACE) program under the MSA Division. With these additions, the FY 85 level of funding that would have kept pace with FY 82 would have been $30M, assuming an annual 4% inflation rate over the past two years. The budget request for FY 85 is $23.0M, or an effective decrease of at least $7M. We recommend an augmentation of $10.0M to bring the total FY 85 funding to $33.0M.

Land-Related Remote Sensing Research and Analysis
Recommended Augmentation $10M

I anticipate that a major element of a Space-Station program will involve studies of the earth from orbit. From this perspective, we can derive the data sets that will permit us to establish the structure and dynamics of phenomena that are global in their respective scales.

The financial support for research and analysis in land-related remote sensing has been reduced dramatically (estimated $48M in FY 79, $37M in FY 83; $15.6M is proposed for FY 85).

The problem here is then two-fold. The university-based research has been cut to the bone, and the need for the results of this research is increasing. In addition, there is an issue of international competition that should not be overlooked. The Congress has decided that the Federal government should retain control of the nation's currently operational weather satellites, and as you know Mr. Chairman there is the possibility that remote sensing operations will be similarly treated. At the same time, Japan, France, and the Soviet Union are moving to commercialize their remote sensing activities. Thus, we should act to strengthen the remote sensing community as required both to maintain U.S. leadership in the field and, as mentioned earlier, to exploit fully the advantages that the capability of the Space Station will offer. To this end, I recommend an augmentation of $10M.

MANAGEMENT AND POLICY ISSUES

Let me next discuss some items that are small in budgetary impact but great in long-term potential value; items that are of direct concern to the R&D community in general and the university-based components of that community in particular. For the most part, these matters have to do with the ways in which we do business in NASA-sponsored R&D. Some concern the fiscal process, others the management or administrative procedures, and still others the technical infrastructure.

Access to Space Flight

One of the most important resources in space related R&D is access to space flight. As you know, in recent years the number of opportunities for space flight has declined steadily, while the intervals between missions have increased steadily, in part because of the growing cost and complexity of space flight missions. In this connection, the start proposed for FY 85 and the recently revived planetary program that includes plans for more frequent missions in the planetary explorer class should offer some near-term relief.

At the same time, however, doubts are growing that the space shuttle will provide, as advertised, an available and easily accessible platform needed for the experiments by university based researchers, i.e., platforms analogous in their uses to the balloons and sounding rockets in the NASA program.

I raise this issue here for two reasons: firstly ,I hope that the managers of the Space Transportation System will renew their efforts to reduce both the cost of doing R&D with the system and the lead times associated with such activities. Secondly, as we look forward to the space station, we must strive to maximize the utility of this new system as a platform for R&D.

Access to Major Facilities

Many facilities of importance to university researchers are too expensive to be procured and maintained by a single university group. Large-scale computational facilities for data processing and numerical modeling constitute an important example. Last November, in testimony before your Committee on Science and Technology, the President's science adviser stressed the importance to the R&D community of access to the latest computational facilities as means both to perform computational work and to develop new computational methods and machines.

The needs for and values of such access are well established, and the other agencies with major R&D responsibilities, the DOD, DOE, and NSF, are moving to achieve this objective. They are expanding the computational facilities as well as the computer communications networks required for efficient access to these facilities.

The needs of the scientists and engineers engaged in NASA funded R&D differ very little from those of their colleagues whose work is sponsored by these other agencies. The computer is an essential tool in almost every discipline. Thus, we require large-scale computational facilities for the processing and dissemination of data from our instruments in space as well as for numerical modeling in disciplines ranging from space plasma physics to aeronautical design.

In recognition of the broadly interdisciplinary aspects of computational facilities, NASA's office of Space Science and Applications has recently established a headquarters office concerned exclusively with information systems. I believe that this step is an appropriate one, and I urge that this activity be given the attention and support necessary to provide NASA-sponsored researchers with the computational facilities and access networks needed for the efficient performance of this research.

The Federal Role in R&D

Concerning the development of commercially viable technology, and here I include technology for which industry's only customer might be the Federal government, e.g., the DOD, an important issue continues to be that of where in a particular R&D effort Federal sponsorship should end and industrial sponsorship begin. In this connection, we have characterized the role of government-sponsored R&D as that associated with the long-term, high-risk phase. Although this description is eminently reasonable, there is a great range of interpretation possible.

I believe we must learn to deal with this delicate matter through an evolutionary process. The finest R&D establishment in the world today, despite its problems, is our own. The distribution of the R&D effort among the vertices of the government-industry-university triangle has evolved in a way that has not really been chart.

I make this point, because in recent years, the indecision on this issue has produced wide swings in the budgets for financial support for various components of our R&D effort. For the most part, these great fluctuations have been unnecessary. Over the short term, they have been wasteful, and, too often over the longer term, they have been unproductive. An example is the painful phase through which NASA's aeronautcial research program has just passed.

Thus, in the R&D endeavor, where major changes in the roles of government and industry, in either financial support or execution, are established as objectives, the associated changes should be carefully planned and smoothly implemented.

Technology Utilization or Transfer

In my work at Los Alamos, I am concerned with both basic research and applied research. In the latter, we come closer to the point at which some of our technological developments can and should be transferred to other agencies and industry. Consequently, I have worked hard to find the formula that governs such transfers. Although I have not found it, I believe that we are already making it work better.

Congress has been instrumental in making it possible for industry to obtain proprietary rights to technology developed with Federal funds, and through the Industrial Recovery Act of 1981, has put the essential tax incentives in place. I am convinced that the university R&D community can and will play a significant role in the process, and I want to endorse NASA's request for $9.5M to continue this activity.

Mr. Chairman and members of the Subcommittee, I thank you for your attention.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION
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COLUMBIA, MARYLAND 21044 • (301) 730-2656
WASHINGTON OFFICE
(202) 547-2900

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14 March 1984

The Honorable Harold L. Volkmer, Chairman
Subcommittee on Space Science and Applications
Suite 2321 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Volkmer:

Thank you for giving me the opportunity to participate in the NASA authorization hearings on February 9. I am enclosing my responses to your additional questions which you were kind enough to forward to me a few weeks ago.

Please let me know if I could be of any further assistance to you and the members of your subcommittee.

Sincerely,

Paul J. Coleman, Jr.
President

Enclosure

KS/hm

Question 1. Dr. Coleman, can you provide us with a general description of equipment allowable for purchase under NASA contracts and grants?

Answer Any kind of equipment needed for NASA sponsored research at a university, is in principle, an allowable purchase under NASA contract and grants. The procurement of any piece of computer equipment must be approved in advance by a NASA contracting officer through an additional procedure. Approval for "special purpose" equipment, i.e., equipment that is useful only on the particular research project for which it is designed, is relatively easily obtained when funds are available and the need is established. Since much of the NASA funded equipment in this category is associated directly with spaceflight missions, the funding has been more typically available. Approval for "general purpose" equipment, i.e., equipment that is useful in many ways on many R & D projects, for example the ubiquitous mini computer, is more difficult to obtain. For understandable reasons, these procurements are more tightly controlled. Furthermore, the costs are usually covered from R & D funds, which, as you know, have been short indeed.

Question 2. Concerning the extra $11 million recommended for university capital equipment:

Question 2a. We have had testimony that at least some of this is included in money already budgeted to go to universities, presumably the various Research and Analysis budgets. If this is true, what does this do to your other recommended additions?

Answer Capital equipment money is indeed included in money already budgeted for universities through conventional grants and contracts. If we can realistically expect stability in the funding of the R & D that NASA intends to support, I believe this approach is the better one over the longer term.

The two situations in which a separate line item is helpful are (1) one in which the capital equipment base has deteriorated to the extent that it has at this time; (2) one in which an extended interval of decreasing funds is forecast, so that special precautions are required to protect research facilities against a reoccurrence of such deterioration.

Since the former situation obtains currently, I recommend proceeding with the special budgetary item for three years.

Question 2b. Should we try to affect NASA's procurement policies to mitigate this problem in future years (your statement, Page 6).

Answer I so recommend.

There is, I am certain, some justifiable percentage of the NASA-wide R & A budget that is appropriate for capital equipment. Unfortunately, in the typical university research group, more often than not, capital equipment requirements occur in relatively large, although relatively infrequent cost increments. Thus, one year no equipment is needed, while a few years later a new computer may be required at a cost comparable to the entire annual operating budget, including salaries, of the group. At the same time, it is seldom that such a group obtains a one hundred percent augmentation in its annual R & A funding, which is the augmentation required in this example.

A separate budget line item for capital equipment discussed in the foregoing, would insure a source of funds for major, infrequent augmentations for this purpose.

An alternative is that NASA treat some fraction of the R & A funds as a capital equipment pool, from which such sporadic augmentations can be drawn and for which protection against withdrawal for other uses is afforded as a matter of agency policy.

Question 2c. What advantages would an identifiable line item for University capital equipment have?

Answer At present, the problem is so severe that something must be done. The budgetary pressures on a principal investigator at a university continue to increase. Although the additional funds in the R & A budget mentioned in question 2a. will help to improve the capital equipment base, they must also correct for other budgetary deficiencies.

I believe the capital equipment problem is now the most critical of the set of problems at hand. Thus,

I have recommended a temporary capital equipment line item as the best way to insure progress toward its solutions.

Question 2d. What can Congress do to promote the implementation of alternative financing plans for capital equipment such as suggested in your testimony?

Answer Research groups at universities are similar in many respects to small (non-profit) businesses. Thus, many of the mechanisms in place to help small businesses could be applied here also at little or no cost other than that covered with grant funds.

In this vein, an important change was effected by OMB last year, i.e., the cost of money was made an allowable expense under a grant to a university.

Other changes could make this allowance more helpful. Specifically, it should be easier for P.I.'s to borrow money for three to five years for certain capital equipment purchases. Some form of loan guarantee, under a temporary program, would help to establish the university principal investigators as creditable borrowers in the commercial market. Under such a program the universities might agree to give the lender first call on the P.I.'S grant funds.

As you know, the National Science Foundation has funded the American Association of Universities (AAU) to search for answers to this question. Also the Universities Space Research Association (USRA) has organized a one day meeting of people from the university community, the financial industry, and government agencies to discuss the matter. The meeting will be held on March 30, 1984. Members of Congress and Congressional Staff are most welcome.

Question 3a. Do you know what kinds of things are not being done in materials processing that could be done with the $10 million recommended increase?

Answer This recommended augmentation to enhance the MPS program would, in addition to the centers of excellence, provide funds for the development of space flight research and processing equipment:

Combustion science is beginning to move from ground based research to flight research. Increased funding for small flight hardware is urgently needed.

A greater emphasis on levitation and positioning devices necessary for containerless processing and research is needed. In addition to current acoustic levitator development, other means such as the electric field levitator which operates without the requirements of a gas atmosphere should be under development.

There is a need for a more precise and higher temperature version of the automated directional solidification furnace for flight on the orbiter's bay.

Very high temperature furnaces and levitation equipment for positioning materials for containerless processing studies would open up vast areas of research into new materials. An example would be the making of glasses from high melting materials, such as yttria, which are very corrosive to a container and therefore could not be made in a pure state. The current mid-deck acoustic levitator and furnace can operate only to about 600° C. Effective work on glasses requires temperatures above 2000° C.

Compound semiconductor devices offer great promise for improvement by space processing. Funding for the precise temperature control furnaces to process this material is needed.

Electrophoresis equipment independent of the commercial equipment shared with MDAC should be built. NASA investigators are hampered in their studies by having to design their experiments around the solutions and other conditions required by MDAC during a particular shuttle flight. Many biological materials which they would like to study cannot be investigated under these conditions. We also believe that advances can and should be made in real time video, larger power supplies, etc., in designing and building the next generation of electrophoresis equipment.

Question 3b. Is there a need for more theoretical or modelling work in this program?

Answer Unquestionably. To a large degree, efforts in the Microgravity Sciences and Applications Division on materials processing in space have focused on conceptualization and execution of experiments aimed at identifying processes or materials that might benefit from a micro-g environment in some way. Accordingly, since one of the advantages of the environment is the low level of buoyancy driven convection, much work deals with systems where fluid motion is involved, viz. preparation of various materials by solidification, crystallization or synthesis and the separation and purification of biological entities using electrophoretic techniques. Experimental results take priority and so experimentalists have established the goals and methodologies.

In more instances that not, however, a full understanding of the relevant fluid motion has been lacking simply because these sorts of problems have received insufficient study to date. The experimentalist whose expertise lies outside the discipline of fluid dynamics finds it difficult to say how buoyancy driven convection effects his process in other than qualitative terms. Similar problems occur when it is necessary to establish what the benefits of micro-g might be vis-a-vis the suppression of convective motion. Moreover, the fact that other sorts of motion might be pre-eminent once buoyancy-driven motions are reduced, while true, is difficult to quantify. Thus, although the experimenter has considerable understanding of how a particular process proceeds in a terrestrial environment, the absence of anything approaching a comprehensive theoretical model with proper attention paid to the fluid motion, precludes efficient experimentation and hinders interpretation.

Another example of an area requiring more theoretical modeling is the effects of gravity (if any) on phase diagrams, eutectic solidification, phase separations, etc.

It is not, however, simply a question of asking the experimentalist to "do some modeling." The activity must be expanded to involve others with expertise in

fluid mechanics, applied mathematics and computation. Each micro-g experimental program should be structured to include substantial modeling and theoretical work to aid in the design of the experiment and the interpretation of results through a comprehensive understanding of the relevant fluid mechanics and transport processes.

Question 3c. The program seems heavily oriented to traditional NASA-type materials, i.e., inorganic materials such as metals, alloys, crystals, ceramics, etc. Is this true? Should more work be done on organics, for example, work that could lead to pharmaceuticals?

Answer Although it is true that the program seems heavily oriented to traditional NASA-type materials (metals, alloys, etc.), it is also true that a great deal of attention is being given to organics. Specifically, NASA has been flying, on nearly every shuttle flight since STS-4, apparatus designed to increase by 400 to 800-fold the capacity to produce purified biological products by moving the process of electrophoresis into the gravity-free environment of space. Both NASA and McDonnell-Douglas Astronautics have spent heavily on this program. A near-future flight will carry an industrial technician aloft to operate the apparatus built by McDonnell-Douglas under a Joint Endeavor Agreement.

This work appears to be leading fairly rapidly toward the development of pharmaceuticals purified in space, but considerable diversification will be required to maintain the pace of the program. Currently four or five laboratories are collaborating on explorations of the use of microgravity technology, but this is not enough, and a broader research base is needed. This broad base will have to include a plan for maintaining the centers of excellence in organic separations recommended last year. The preliminary bench-testing of separation concepts normally precedes space experiments, and good laboratories must be maintained for the post-flight analysis of processed materials returned from space.

A sensible budget to support continued research into organic purifications in space should (1) assure the availability of space flight equipment for designed experiments, (2) continue to support bench-testing

of purification concepts in university and institutional laboratories, (3) assure the availability of laboratory facilities and trained personnel to analyze purified organic materials returned from space, (4) facilitate the timely funding of investigator-proposed projects, and (5) attract high-quality investigators into microgravity processing research.

Question 4. What kind of work do you think should be done in the augmented remote sensing program you recommend?

Answer The work that is needed is well stated in two documents recently published by the NASA Earth Science and Applications Division and Life Sciences Divisions, "Land-Related Global Habitability Science Issues" and "Global Biology Research Program Plan." These demonstrate the need for research directed at fundamental issues affecting the long term habitability of the Earth. Produced by working groups of distinguished university and industry scientists, these documents call for research on a broad range of topics, from using combined satellite, aircraft and surface sampling to improve our understanding of the spatial and temporal dynamics of major land cover types, to assessing the biomass and net primary productivity of global ecosystems. Such studies would provide important information on issues of critical national and international concern, including the carbon dioxide problem, deforestation and desertification. Despite the budget cuts which have occurred in terrestrial Remote Sensing, significant capabilities are still available. The $10 million augmentation can certainly be used wisely. USRA strongly recommends approval of this proposed augmentation.

Question 5. Do you envision that current NASA initiatives, such as Spartan and the Getaway Special, to provide better access to space platform will result in a healthier space science and applications program within the academic community?

Answer With the creation of the Spartan and Getaway Special programs, NASA recognized the importance to research of introducing to the shuttle, simple, low-cost experiments. Programs in this direction are welcomed by university researchers.

Spartan, in particular, makes use of the existing technology employed in experiments previously carried by sounding rockets. Not all scientific areas utilizing sounding rockets, however, are able to transfer experiments to a Spartan subsatellite. Spartan is not, and should not, be intended as a total replacement.

Certain studies, particularly high-energy astrophysics, solar physics, and ultraviolet astronomy can benefit from the vastly increased observation period available to a Spartan subsatellite. A flight duration of up to 40 hours is available - an increase of 100-1000 times that provided by sounding rockets.

The philosophy of the program: Keep it simple, and keep the cost down, is a philosophy essential to a great many scientific investigations in the space sciences.

Question 6. How can we assure better access to major facilities? (Your statement, page 12)

Answer In my remarks on March 9, I commented on the needs for access to large scale computational facilities. Several such facilities exist or are being developed. For these computational centers, computer communications networks linking the campuses to them will satisfy a major component of these needs. Well defined and published procedures for obtaining on-site access for visiting university researchers should satisfy the rest. Progress is being made on both fronts but continued attention is needed.

For major facilities of other kinds, I would like to see increased use of certain arrangements that are already being used successfully. Here I categorize as major facilities, those that are needed by researchers at many universities and too costly to be replicated at the various user campuses. Examples are high energy particle accelerators and astronomical observatories. Such facilities have been successfully developed and operated by the multi-purpose national laboratories operated by universities, industrial concerns and university consortia, and as separate facilities operated for the most part by universities and consortia of universities.

NASA should seek to define the needs of NASA sponsored researchers for such facilities. Also, I believe certain of the national laboratories should participate more on facilities projects of this nature.

Question 7. One suggestion for improving technology transfer is to involve users from the beginning (your statement, Page 13). In the case of space technology, this can be difficult. For example, 15 years ago there were no Landsat users. What can we do about that?

Answer The premise upon which question 7 is framed is perhaps misleading. Although there was no "Landsat user community" 15 years ago, a considerable community was using aerial photography and other forms of remotely sensed data. There were scientists and technicians in Federal and State agencies, private industry and universities, who knew and used these data, and could advise on the potential of Landsat type technology. The bottom line is that there is a wide variety of knowledgeable users, and these individuals must be involved in the development of space technology. This can be accomplished through organizations such as the National Academy's Space Science and Space Applications Boards, industry consortia, and university consortia.

The need for universities as basic research and technology transfer agents is vital to the long term acceptance of space technology. Studies have shown that in states where the NASA Office of University Affairs had a University Applications Program, state agencies had statistically higher levels of acceptance of Landsat technology than those in states with no comparable programs. Closer cooperation between Federal science agencies and the university community is certainly warranted.

More specifically, while it is true that the potential users may not be easily identified we must simply try harder because the stakes are higher.

Question 8. Some of your recommendations, particularly those which would create new budget line items identifying

university outlays, seem to create a new dimension to NASA's mission. That is, "support universities."

Answer I should comment first that I wouldn't characterize such support for universities as a new function for NASA. Rather it is a renewal of a NASA program that was strong in the 60's. (See reference #1 in my prepared remarks of January 9.)

Question 8a. Why should we do this when NSF already has such a mission?

Answer I find that, in practice, the National Science Foundation looks to NASA to support the space related R & D at the universities, including the plant and equipment needed for this R & D.

Question 8b. Would you make similar recommendations to other science agencies?

Answer I would. NASA and many other agencies support basic research and technological development at universities in disciplines that are relevant to their respective missions.

These agencies have recognized that there are in many cases special benefits to them in sponsoring work on the campuses. I would ask that they recognize also that these benefits are derived from the special conditions on the campuses, e.g., student participation and the associated intensity of the research effort, long term commitment of the faculty researcher and the associated continuity of this effort, and the absence of potentially inconsistent additional objectives such as financial profit.

I would ask further that the sponsoring agencies recognize that these special conditions, if they are to be maintained, require that special responsibility be carried by the sponsors, e.g., stability of funding needed to encourage the five-year commitment of a graduate student and the longer term commitment of a faculty member, and the level of funding needed to acquire and maintain modern facilities.

Furthermore, I do not believe that the National Science Foundation should be asked to support all of

the costs of the university research community except those directly applicable to the sponsored research of another agency. Thus, to use the recurring example of equipment, I do not believe that the National Science Foundation should be expected to fund all of the general purpose equipment that is used by a university scientist for DOD sponsored research.

Question 9. Do you think there is any merit in targeting less prestigeous universities for awards?

Answer There is a great merit in encouraging scientists at such universities to compete for research funds. However, I believe all of the usual criteria for selection of research proposals should be applied here also. There is ample evidence to the effect that if these criteria are not met, the research project will be a failure. The net result is likely to harm rather than help the home institution. Thus, I recommend against "targeting" in the sense that the targeting process would include preferential treatment through lowered standards.

Mr. VOLKMER. Thank you very much, Dr. Coleman.

Before we go to questions, we will now hear from Dr. Banks.

Your statement, of course, will be made a part of the record. You may either summarize or review it in full. You may proceed, Dr. Banks.

Dr. BANKS. Thank you, Mr. Chairman. I greatly appreciate the opportunity to testify before you on issues relating to the development of the space station. My appearance is not as general as that of Dr. Coleman's. I am here because of my recent acceptance of a request by NASA to create a Space Station Advisory Committee, and I would like to discuss that with you, giving some of the history and the intent of that particular activity.

The information I present to you is based on written materials and oral conversations conducted with NASA during the month of January, when I was first approached to create this particular advisory committee. In the subsequent weeks, I have been very much engaged in soliciting opinions and advice from professional colleagues and professional groups with respect to membership on this particular committee.

In my testimony today I will go through both the progress that I have made, the charge given to us by NASA, and some of the expectations I have concerning the role of the committee during the next 2 years.

It is the intent of NASA that the chairman of the Space Station Advisory Committee will be a member of the Space and Earth Science Advisory Committee, which you know reports to the Associate Administrator for Space Science within NASA.

Members of the new committee have not yet been formally accepted by NASA, and as the prospective chairman, I have been taking a great deal of care to go through the various processes one needs to take in order to be sure of getting mature, highly qualified individuals to represent the broad range of activities that are conducted within the Office of Space Science and Applications.

I envisage approximately 20 members to this committee. It will include membership in the life sciences, materials sciences, microgravity research, the traditional space science activities, as well as applications. One of the challenges I have faced during the past 2 weeks is not only to convince people who are already overburdened with professional and technical responsibilities that this is a worthwhile activity, but to be certain that they represent the best individuals that are present to provide advice to NASA.

Because NASA must appoint these people in a formal way—this is an advisory committee—I suspect that we will not be able to have our first meetings until late March or early April of this year.

Both from your point of view and that of the Nation's space research community—and by that I mean both science and applications—it is important that there be a clear understanding of the tasks and responsibilities given to this new committee. The history of space science and applications research during the past decade has shown the difficulties that can arise with the introduction of new space technology. I, as an experimenter, have been very closely involved with that transition, having experiments both aboard the space shuttle and earlier spacecraft. I can say frankly that the space shuttle development years have been very hard upon space research, both in terms of reduced flight opportunities, which Dr. Coleman mentioned a few moments ago, the increasing emphasis upon large singular projects having great costs, and a general decline in the funds available to universities to conduct basic research, data analysis, and for capital equipment acquisition.

With a history like this, it is clear that proposals for using the space station as a base for further scientific activities in space receive only grudging support from many scientists. I think in the newspapers and public magazines you can see this type of response.

In their view, the space station, irrespective of its great potential for new scientific endeavors, will be a significant drain upon funds already in short supply. I will return to this at the end of my testimony today. But what I would like to do now is tell you the specific tasks I see the specific committee to have.

These are quotations from a letter given to me outlining my responsibility and that of the advisory committee. First, we are charged with assisting NASA in planning for the scientific utility of the space station. Second, we are to act as a focal point for broad scientific community input into space station activities. And if the indication from the public press and journalists recently is any measure, that is going to be a major activity, to simply act as a focus and communicate external information into NASA.

Third, to assist NASA in understanding the relationship between the new capabilities of the space station and the existing space science and applications program. Previously, Professor Donahue, on behalf of the Space Science Board, has testified on a number of aspects of the existing space science and applications program, and it is clear there is a great deal of concern in that particular area. I will return to that in just a moment.

The fourth task is, to periodically update scientific requirements on space station hardware and operations. I regard that as a particular duty but one which is probably not as important as the first three.

Finally, they have requested that we interact with contractors, the great phalanx of contractors who will participate in this activity, during the definition phase of space station development.

The lifetime of this committee is set at approximately 2 years at the present time.

I would like to comment on the planning of the scientific utility for the space station. I have personally been involved in that for a period of probably a decade within my own scientific discipline. Workshops and other meetings have been held among all scientific disciplines to examine the utility of coordinated facilities, having a scale and complexity not accommodated on automated spacecraft.

The studies conducted in many disciplines, including life sciences, materials research, solar-terrestrial research, and earth observations have all considered opportunities offered by a large resource space station, and in all cases concluded that important tasks could be effectively accomplished with this facility or facilities coordinated with it.

It is important to note that much of this advance planning was based upon assumptions about the availability and usefulness of human resources in space. Although the scientific activities in the skylab missions provided certain benchmarks, it was not until very recently that the full value of mission and payload specialists could be fully appreciated.

Mr. Chairman, I think if you have listened on the circuits to activities on spacelab I, in particular, you will remember that there were many opportunities for the crew not only to govern and guide the progress of experiments to make essential repairs that guaranteed the success of both the European and American experiments.

For certain disciplines not fully represented in the present-day spectrum of space-related research, the active intervention of onsite specialists is not only helpful but essential.

Another related point is the realization that a monolithic space station would serve only a narrow range of scientific interests. Many conflicting requirements for the local environment, viewing, accuracy of viewing, orbital inclination, and orbital altitude, necessarily argue that there should be a wide variety of scientific platforms which are relatively autonomous, but connected through resource capability, to the main station.

If you have had an opportunity to look through the contractor reports to NASA, the eight contractors, you will find that the same attitude prevails there, that there must be not a single laboratory internally oriented, but opportunities for a variety of activities, some of which may be remote from the main station itself.

The second task of the advisory committee will be to act as a focal point for scientific concerns regarding space station activities. Already there have been serious comments about the projected nature of the space station research studies. The Space Science Board of the National Academy of Sciences has said that their present list of scientific objectives can do without the space station for the next 20 years. While such criticism deserves serious thought, it must also be pointed out that in the absence of any approved plans to implement a space station, future missions have been developed around current concepts of freeflyers and the space shuttle. The potential gains offered by a space station complex of

laboratories and associated platforms with human resources have not been incorporated into their ideas. As indicated by a number of reports, there are many disciplines which would welcome the opportunity to participate in space station investigations.

I feel that the opinions of the national scientific community can be brought to NASA's attention in a forceful manner through the Space Station Advisory Committee, both through direct discussions, which are always important, and through progressive written reports.

As you are aware, there is presently a concern that designs for the station and plans for funding and implementation will ignore legitimate scientific objectives. During the past decade the broad goals of space research have been distorted by the demands of the space shuttle technology with delays, higher than anticipated costs, and the need to maintain an engineering infrastructure which does not lend itself directly to scientific productivity. I myself am faced with just that situation currently on the spacelab II activity, which although it was designed for earlier flight, I now maintain quite an engineering crew at some cost and not necessarily to this question of scientific productivity.

It is my hope that this situation will not develop again, and I think I echo the hopes of the entire scientific community, and certainly not through the lack of pointed scientific comment given directly to NASA through a formal advisory mechanism.

The third task, that of assisting NASA to understand the relationship between the new space station capabilities and the national space research program, is truly significant. This Nation supports a broadly based program of investigative research, many elements of which simply cannot use the resources of a space station. Examples of this include university theoretical research, discussed by Dr. Coleman previously, data analysis, topics relating to Earth's magnetosphere, solar wind, and planetary exploration itself. Adequate funds to support these segments of the space program must continue to assure scientific vitality, accomplishments, and national leadership.

A related concern is the role to be played by this Nation's universities. The partnership discussed by the President was directed towards industry, with the goal of commercialization of space. Mr. Chairman, I would like to emphasize that universities in this Nation also have much at stake with respect to space station development, and they, too, deserve to participate in many of the engineering and scientific activities of NASA.

Although the scientific relationship between NASA and the university community has received much attention in the past, I feel that university-level space engineering research has much to offer and has been relatively neglected. Presently, I see no extensive commitment by NASA to exploit this resource, especially with respect to the space station activity. I would hope that NASA would use the space station project as an opportunity to revitalize its relations with the university research programs of this Nation, bringing them directly into activities supportive of space engineering and space science.

Mr. Chairman, on the walls of this room we see images of the past. We see the history of Apollo, skylab, the earlier programs

Mercury and Gemini. And we also see primarily artist's conceptions of the space shuttle. That will change with time. I hope that within a decade you will have pictures rather than artist's conceptions of the space station, showing its true utility to science and to applications.

This concludes my formal testimony. I would be pleased to answer any questions you may have. Thank you.

[The prepared statement, plus answers to additional questions asked of Dr. Banks follow:]

PREPARED STATEMENT OF PETER M. BANKS, PROFESSOR AND DIRECTOR, SPACE TELECOMMUNICATIONS AND RADIOSCIENCE INFORMATION SERVICES, DEPARTMENT OF ELECTRICAL ENGINEERING

Mr. Chairman and Members of the Subcommittee:

Thank you for your invitation to testify on issues relating to the development of the space station. My name is Peter M. Banks. I am a Professor of Electrical Engineering and Director of the Space, Telecommunications and Radioscience Laboratory (STARLAB) and the Center for Aeronautics and Space Information Sciences at Stanford University. My appearance before you is based upon my recent acceptance of a request by NASA to create and lead a new advisory committee devoted to assisting NASA in planning for scientific uses of the space station. Through communications with your staff, I understand that this subcommittee has an important interest in this activity and wishes to learn more about the advisory committee, including its organization, terms of reference, and anticipated tasks. In the following discussion I will give you my understanding of these topics, as well as my own thoughts on some of the crucial issues surrounding the development of science activities within the space station concept.

The information I present to you concerning the advisory committee is based on written materials I have received from NASA, as well as extensive conversations with Dr. Jeffrey D. Rosendhal, Assistant Associate Administrator (Science) for NASA's Office of Space Science and Applications, and others within this same organization. This new advisory committee is being created under the auspices of an already existing advisory committee: The Space and Earth Science Advisory Committee (SESAC), which provides advice to the Associate Administrator for the Office of Space Science and Applications. The name to be given to the new advisory committee is: The SESAC Task Force on Scientific Uses of the Space Station.

It is the intent of NASA that the chairman of the space station advisory committee will be a regular member of the SESAC, and that regular members of the committee will become associate members of SESAC. Members of the new committee have not yet been formally accepted by NASA. As the prospective Chairman, it has been my responsibility during the past two weeks to create a balanced list of proposed members, taking into account the spectrum of science and applications research within NASA. I have received suggestions about potential members both from NASA as well as many colleagues who are members of other advisory and professional committees. I intend that each member recommended by me shall be clearly outstanding in his or her field of research and that they shall possess a maturity of scientific thought to insure that they can evaluate space station scientific potentialities within the overall scope of this nation's program of space research. I anticipate recommending 20 persons for membership on this committee and that formal appointments by NASA will take about 45 days. Thus, the first formal gathering of the committee will be in late March or early April of this year.

Both from your point of view, and that of the nation's space research community, it is important that there be a clear understanding of the tasks and responsibilities given to this new committee. The history of space science and applications research during the past decade has shown the difficulties which can arise with the introduction of new space technology. The space shuttle development years have been hard upon space research, both in terms of reduced flight opportunities, the increasing emphasis upon large, singular projects, and a decline in the funds available to universities to conduct their basic research and data analysis. With this history, it is clear that proposals for using the space station as a base for further scientific activities in space receive only grudging support from many scientists. In their view, the space station, irrespective of its great potential for new scientific endeavours, will be a significant drain upon funds already in short supply. I will return to this issue, as well as the question of manned versus unmanned activities in space, later in this testimony.

NASA has set five important, specific tasks for the space station advisory committee. These are:

1. To assist NASA in planning for the scientific utility of the space station.

2. To act as a focal point for broad scientific community input into space station activities.

3. To assist NASA in understanding the relationship between the new capabilities and the existing space science and applications program.

4. To periodically update scientific requirements on space station hardware and operations.

5. To interact as needed with contractors during the definition phase of space station development.

In my opinion, it is the first three of these tasks which give the committee its great responsibility and through which its success will be measured. I would like to comment upon these in the order given.

Preparation and advocacy for scientific use of the space station has been underway in the science and applications communities since the early 1970's. Workshops and other meetings have been held among scientific disciplines to examine the utility of coordinated facilities having a scale and complexity not accomodated on automated spacecraft. Studies conducted in many disciplines, including the life sciences, materials research, solar-terrestrial research, and earth observations have considered the opportunities offered by a large resource space station and have concluded that important tasks could be effectively accomplished with this facility or facilities coordinated with it.

It is important to note that much of this advance planning was based upon assumptions about the availibility and usefulness of human resources in space. Although the scientific activities in the Skylab missions provided certain benchmarks, it was not until very recently that the full value of mission and payload specialists could be fully appreciated. During the past two years there have been many instances aboard the space shuttle where scientific experiments have had the opportunity to use such talents in the conduct of observations or for repair of instruments. For certain disciplines, not necessarily fully represented in the present day spectrum of space-related research, the active intervention of on-site specialists is not only helpful, but essential.

Another, related point is the realization that a monolithic space station would serve only a narrow range of scientific interests. Many conflicting requirements for the local environment, viewing, accuracy of viewing, orbital inclination, and orbital altitude necessarily argue that there should be a wide variety of scientific platforms which are relatively autonomous, but connected through resource capability, to the main station.

The question of automation of space observations has been another topic of discussion. There is no doubt that automation is a desirable characteristic and there are presently no instruments designed for space operations which don't include extensive capability in this direction. However, the advocates of automation imply that complete automation is more desirable than a moderated state of development where human presence can be effectively used. In certain situations, such as our current plans for planetary exploration, such an attitude is understandable. However, the perfection of automated machinery and electronics with appropriate artificial intelligence and expert systems lies far in the future, and our plans for activities in the space station must recognize the great value of human intelligence and direct intervention with instruments and malfunctioning equipment. In fact, one of the great challenges of the space station instrument designs will be to incorporate internal diagnostics and repair capabilities which are consistent with space station resources and costs.

The second task of this committee will be to act as a focal point for scientific concerns regarding space station activities. Already there have been serious comments about the projected nature of the space station research studies. The Space Science Board of the National Academy of Sciences has said that their present list of scientific objectives can do without the space station for the next twenty years. While such criticism deserves serious thought, it must also be pointed out that in the absence of any approved plans to implement a space station, future missions have been developed around current concepts of freeflyers and the space shuttle. The potential gains offered by a space station complex of laboratories and associated platforms with human resources have not been incorporated into their ideas. As indicated by a number of reports, there are

many disciplines which would welcome the opportunity to participate in space station investigations.

I feel that the opinions of the national scientific community can be brought to NASA's attention in a forceful manner through the space station advisory committee, both through direct discussions and through written reports. As you are aware, there is presently concern that designs for the station, and plans for funding and implementation, will ignore legitimate scientific objectives. During the past decade, the broad goals of space research have been distorted by the demands of the space shuttle technology with delays, higher than anticipated costs, and the need to maintain an engineering infrastructure which doesn't lend itself directly to scientific productivity. It is my hope that this situation will not develop again. And certainly not through the lack of pointed scientific comment given directly to NASA through a formal advisory committee mechanism.

The third task, that of assisting NASA to understand the relationship between the new space station capabilities and the existing national space research program, is significant. This nation supports a broadly based program of investigative research, many elements of which cannot use the resources of a space station. Examples of this include university theoretical research, data analysis, and magnetospheric, solar wind, and planetary exploration. Adequate funds to support these segments of the space program must continue to assure scientific vitality, accomplishments, and national leadership.

A related concern to this is the role to be played by this nation's universities. The partnership discussed by the President was directed towards industry, with the goal of commercialization of space. Mr. Chairman, I would like to emphasize that universities in this nation also have much at stake with respect to the space station development, and they, too deserve to participate in many of the engineering and scientific activitites of NASA. Although the scientific relationship between NASA and the university community has received much attention in the past, space engineering seems to have been increasingly neglected. I feel that university level space engineering research has much to offer to this project. Presently, I see no extensive commitment by NASA to exploit this resource. I would hope that NASA would use the space station project as an opportunity to revitalize its relations with the research universities of this nation, bringing them directly into activities supportive of space engineering and science research.

Mr. Chairman, this concludes my formal testimony on the subject of the NASA advisory committee for scientific uses of the space station. I would be pleased to answer any questions from you or your subcommittee.

Space, Telecommunications And Radioscience Laboratory

29 February 1984

Rep. Harold L. Volkmer, Chairman
Subcommittee on Space Science and Applications
Committee of Science and Technology
Suite 2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Mr. Volkmer:

I was pleased to be of service to your subcommittee by providing testimony on my participation in the establishment of NASA's Task force on Scientific Uses of the Space Station. I feel this advisory group will be of significant help to NASA in formulating plans both for effective scientific development of the Space Station, as well as providing information concerning the timely development of policies relating to the way Space Station will fit into NASA's ongoing program of space research.

My responses to the further questions posed in your recent letter are given separately. I would be pleased to correspond with you further on any of the topics if you so desire.

Sincerely yours,

Peter Banks

Peter M. Banks
Professor and Director
STAR Laboratory

Encl: Responses to Rep. Volkmer

STAR Laboratory
Department of Electrical Engineering/SEL • Stanford University • Stanford, CA 94305
Telex No. 348402 STANFRD STNU

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

Additional Questions for Dr. Banks

1. There is some concern that the Space Station effort at NASA, one way or another, inadvertently or without malice, may adversely impact the Space Science and Applications program.

   a. How do you think your Task Force will actually work? What will you do?

   b. Will your task force deal with applications as well as science? If not, who is responsible for applications?

2. Your Task Force will provide an important focal point for the scientific community.

   a. What assurance do you have that your input will be taken seriously by the Space Station design and planning teams?

   b. Do you envision that your input may be mistaken for an endorsement of doing all science on the Station (and thus simply an alternative to the view expressed by the Space Science Board)?

   c. What is the relationship between your Task Force and the Space Station Task Force and Commercialization Task Force?

   d. What will be the relationship between your Task Force and Johnson Space Flight Center?

   e. What other sources of science input do you think the Space Station planners will have?

   f. Will your recommendations have any impact on the level of funding science projects will have?

   g. Will you be able to provide information and advice directly to the Committee on Science and Technology if asked by us? On your own initiative?

4. What type of interaction do you envision between your Task Force and contractors involved in Space Station planning and design?

5. Will your Task Force lifetime extend past the development phase of Station?

6. We have heard testimony from the Chairman of the Space Science Board of the National Academy of Sciences that unmanned platforms can perform at least some if not most of the science currently envisioned.

   a. Where do you see the value of human intervention that cannot be obtained from ground controllers?

   b. Do you see any of your responsibilities as rejecting some science on the basis that unmanned platforms may be more cost-effective?

7. How would you assess the relative priority of doing basic research vis-a-vis commercial exploitation of the Station (for example for long-term materials processing)?

8. Most of your testimony references your responsibilities in relation to the "national scientific community", "this nation's universities", etc. Yet we have heard of NASA's desire for international collaboration.

   a. Which do you think NASA will consider the higher priority?

   b. How can you ensure that U.S. scientists and universities receive proper emphasis during the experiment selection process and Space Station planning and development?

9. Your testimony indicates that NASA should do more to take advantage of University capabilities in space engineering research.

   a. What can we do to ensure that this happens?

   b. What would you consider to be an appropriate level of undertaking by the university community with respect to the Space Station?

10. Generally, how can we avoid "force feeding" science into the space station? That is, how can you ensure that we don't force science to fit a space station format and protocol when other approaches may be more appropriate?

    a. Specifically, what steps can be taken to make Station friendly to science?

    b. Why is the Shuttle seen as difficult to work with?

    c. Do you consider the "Space Shuttle" to be a proper platform for Gravity Probe-B?

11. On a different subject, do you have any comments about your own scientific field?

    a. Do you feel there should be a division of Solar-Terrestrial Physics (or equivalent) in NASA?

    b. Do you believe the OPEN program is adequately funded?

Responses by Prof. Peter M. Banks to Written Questions Posed by Rep. Harold L. Volkmer, Chairman, House Subcommittee on Space Science and Applications

February 29, 1984

1.a. The Task Force on Scientific Uses of the Space Station will be composed of approximately 20 persons selected on the basis of their professional qualifications with respect to disciplines relating to space science and space applications. This group will meet approximately four times per year to discuss NASA's plans with respect to Space Station. Advice will be given on a variety of topics, including the suitability of Space Station accomodations for the broad range of anticipated science and application programs, the mix of scientific projects to be actually undertaken in connection with the new platforms, the funding allocated to advanced science and applications planning and experiment implementation, and the relation of the new capabilities to older, well established NASA programs.

I anticipate that this advisory committee will serve as a focal point for scientific comment external to NASA with respect to Space Station science and applications activities, and that during our public meetings there will be opportunies for persons not directly connected with NASA research activities to present their opinions and suggestions with respect to space station utilization for scientific purposes.

I also expect that this advisory committee will provide insight to NASA with resepct to the balance of activity between the existing program of applications and science research, which involves many different platforms, and the new capability offered by the Space Station concept. The funding profile and eventual pattern of Space Station funding is of crucial importance to the broad scope of this nation's space research program and, hence, will be part of this committee's deliberations.

1.b. Yes. Special care has been taken to include a number of members who will respresent the activities covered under the general category of "Applications". This includes remote sensing of Earth's oceans, landmasses, and atmosphere, microgravity specialties with materials and other research, and topics relating to human physiology and psychology, biology, and so forth.

2.a. I have received personal assurances from The Associate Administrator for Space Science and Applications that the advice given by this committee will have an important impact upon his plans for the science and applications plans formulated by his office for development of Space Station. I have also had direct discussions with Mr. John Hodge, which lead me to believe that he, as the leader of the Space Station Task Force, believes that the advice of this

committee will have an important impact upon the planning currently underway in the space station organization.

2.b. It is my hope that the advice given by this committee is not regarded as a blanket endorsement of all of NASA's aspirations for the Space Station project. There is a broad spectrum of endeavor in NASA's program of space research, and my own point of view is that the various platforms offered by the Space Station concept will each have to be justified within the overall goals of conducting space research in an expeditious, cost effective manner. In particular, great care must be taken to evaluate the particular advantages offered by the Space Shuttle, the Space Station unmanned platforms, as well as payloads associated with unmanned launch vehicles, rockets, and so forth.

2.c The Space Station Task Force is an internal NASA activity, is, I believe, the Commercialization Task Force. The Task Force on Scientific Uses of the Space Station is an independent advisory committee which reports into the NASA advisory committee system through the already existing Space and Earth Science Advisory Committee. As such, there is no formal connection to the other internal NASA Task Forces.

2.d. There will be no direct relationship, although I presume that JSC representatives would be present at our meetings.

2.e. There is an internal Space Station committee composed of representatives from each of the NASA Centers as well as members from NASA Headquarters. This internal committee will have access to the various science and application development plans generated through NASA discipline oriented projects.

2.f. It is my hope that our advice will guide NASA managers in the development of their plans for science and application activities on Space Station, as well as for the transition years with Space Shuttle operations.

2.g. It is my intention that the recommendations of this advisory committee would be generally available to all interested parties. The meetings will be conducted in public places, and our deliberations open to all. We would welcome the opportunity to interact with you and your staff in a manner best suited to your needs.

3. (No question was posed)

4. It is my understanding that there will be some interaction between various NASA contractors and this committee. If there are particular questions posed by the contractors, it is my presumption that the committee would undertake to provide advice, if deemed appropriate. In any case, I forsee a desire on the part of the committee to be kept aware of contractor design philosophy and plans during the conceptual

design phase of the Space Station project.

5. It is my understanding that the lifetime of this committee is currently set at two years. Extension beyond this will depend both our usefulness to NASA and the desire of the science and applications community to have what is clearly a unique opporunity to provide formal advice conerning an important tool for conducting research in space.

6.a. There is no doubt that unmanned platforms are essential for space research. In this situation, fully automated equipment with great internal redundancy must be developed and tested in order to operate correctly in the space environment. Furthermore, in recent years, with the great advances in microelectronic technology and telecommunications, it has become possible to conduct extensive scientific experimentation aboard spacecraft from the ground, taking advantage of both pre-programmed operations, and interactive experiments where, based on data received from space, ground scientific personnel can alter the observing programs and settings required to perform the observations.

Such automated activites come at great cost, both in terms of the advance planning which must be done and the care which must be taken to ensure virtually perfect operation of the mechanical and electrical equipment. Furthermore, the designs of the instruments must include ways of meeting very broad ranges of operating conditions and contingencies which may occur in space. For certain types of observations, where an advanced level of observational maturity has developed over the past several decades, such designs can be drawn with a fair degree of confidence that the automated instruments can be designed and successfully flown. Space Telescope is an example of such an activity.

The inclusion of the human component in space research is an important aspect of the Space Station concept and one which has progressed significantly through Skylab and recent Space Shuttle missions. The role of trained mission specialists in performing repairs on balky equipment is, in my opinion, a forerunner of a human-machine synergism which, for certain classes of space research activity, will prove to be of great importance. Up to the present time, only slight effort has been spent designing instruments and support equipment which is both self-analyzing and repairable (in a modular sense).

A more important aspect of mission and payload specialists will be their active participation in scientific activities aboard the Space Station. Interactive experiments using the visual and integrative aspects of human capabilities will be needed in situations where novel approaches or new classes of phenomena are involved. In these situations, the manipulative and cognitive abilities of a locally situated scientist have been been shown to be far superior to the efforts of a remote, partially informed ground controller. I forsee

many new classes of space activities where ground and space observers intimately interact in the course of experiments and observations.

The argument that experimental activities could be better done from the ground using fully automated mechanical and electrical equipment is often advanced as an argument against having an extensive human component involved in Space Station science activities. In my opinion, fully automated observatories and laboratories are not a practical reality at the present time, and will not be for many decades. With the present state of mechanical and electrical perfection, such activities will always be subject to failure. Thus, while automation as an aid to scientific activities is always desirable, it should be regarded as a tool whose value must be evaluated within the context of its application and capability. Since Space Station will involve a human presence, we must be certain that the concept of automation and machine-based information systems are used to supplement the efforts of the payload and mission specialists who will be present.

6.b. Since the Space Station concept includes the use of several unmanned platforms, this question is difficult to answer. I expect that there will be a number of unmanned platforms which can call upon resources offered by the central Space Station; e.g., initial testing and checkout, periodic replenishment of consumables, retrieval of malfunctioning apparatus, etc. I can also visualize that there will be other unmanned platforms whose orbits make periodic visits very expensive, even if catastrophic failures have occured. Such platforms then become, perhaps, unassociated with the resources offered by Space Station. In assessing whether a given unmanned platform should be launched to take advantage of Space Station resources will be both a question of economics, utility gained, and timing.

7. Both activities deserve support from NASA. The partial return of costs offered by the commercial enterprises should not be a major factor in determining the relative priorities involved. NASA has a responsibility to both conduct basic space research and to foster commercialization of space.

8.a. Principal support for NASA's space research activities comes from scientists and engineers in the United States, and I believe they should have first call upon the resources of the Space Station, if those resources are in short supply. Cooperative international ventures are acceptable to the extent that they enhance our own national programs and needs. It is inevitable that international political considerations will impact NASA's plans, but there must be a realization of their impact upon U.S. space research opportunities.

8.b. Great care must be taken to ensure that the terms of selection for flight opportunities do not make difficult participation by U.S. institutions. Agreements between NASA Centers and corresponding foreign national institutes can, for example, lead to reduced

participation by U.S. universities as a consequence of the non-competitive choice of and NASA Center groups to carry out portions of the scientific work.

9.b. There must be a realization within NASA Centers and at NASA Headquarters of the contributions which can be made by research oriented universities. The establishment of block grant engineering research programs at selected universities would serve not only to train engineering graduate students in topics related to space, but would also bring significant faculty participation on advanced subjects. The impact of such research would be favorable to NASA, bringing new talent to the agency as well as the fruits of the research work itself.

There must be a realization that the technical partnership between NASA, including its Centers, and industry must be expanded to include universities in a role to which they are best suited: Long range, fundamental research into topics which have long term importance. Particular topics might include space telecommunications, large space structures, advanced materials research, advanced electronic design for the space environment, applications of automation and expert systems, and so forth. Many of these activities are already underway, but at universities they are offered in the traditional formats of short term grants and contracts. The extension to long term (3 to 5 years) support conducive to university participation is important since it determines faculty and student dedication.

Congressional discussion and support would be helpful in convincing NASA that such programs would be important to its longterm mission.

10.a. Great care must be taken to ensure that the science accomodations aren't locked into a fixed state of technology. The design of the Space Station must incorporate a philosophy of technical change to match the rapidly changing tools available for conducting experiments and observations in space. Special care must be taken to provide very good bi-directional communications, including observational data links, instrument command links, voice, and high resolution video. The benefits of fully developed information systems with local (on the Space Station) and remote processors must be realized in a format which enables advances in microelectronics technology to be rapidly incorporated into the support systems. These developments should take place in the context of generally accepted commercial standards. The adoption of "NASA-only" standards must be avoided to insure the utilization of commercially available hardware and software.

The advances described above apply to both the Space Station activities and to the ground support facilities where research workers will participate in the ongoing observations and experiments. This implies the development of a decentralized system of science operations control activities, perhaps even at the Principal

Investigator level, where research teams would be able to participate in Space Station technical activities without leaving their home institutions.

Another aspect of this problem is that of reducing the time required to prepare for a mission. Presently, all science activities on the Space Shuttle are highly preprogrammed, with little opportunity to pursue alternate activities based on the results of the ongoing experiments and observations. Great effort is now spent in preparing for single flights, and the cost of this is enormous since there are significant penalties for failure and/or injudicious use of precious flight time. While it is impossible to do away with all such advance planning for even the Space Station, NASA must find a more balanced approach for conducting research in space which will reduce the manpower needed to support in-space science activities. Reductions in cost brought about by this relaxation of preparation will yield significant dividends since each discipline supported by NASA will then have more "science per buck".

10.b. The Space Shuttle is difficult to work with for a variety of reasons. First, the resources available on orbit are limited. Power and total energy is in short supply, and support facilities, including telecommunications, computer processing and control, and technical crew support must all be rationed among large groups of investigators. Mixtures of experiments lead to competition for particular vehicle attitudes and other environmental choices. Since the missions are very short, a high degree of planning is required in advance and on-site innovation is discouraged. In the present planning schemes, there is no time for failures or pursuing alternate paths based on realtime decisions arising from unexpected results.

10.c. My understanding of the technical requirements Gravity Probe-B experiment is limited, but based upon the technology developments I have seen, I would feel that this experiment would be better suited to a free-flyer away from direct contact with the Space Shuttle. The physical effects being measured manifest themselves only slowly, and inadvertent interference caused by Shuttle-related activities could be damaging.

11.a. Yes, I feel that creation of a new division within NASA devoted to Solar-Terrestrial Processes would be of great benefit to the community of workers devoted to research related to physical process occuring within the Sun-Earth system. Such an office existed previously and served a useful purpose in giving focus to the activities falling within its charter.

11.b. The OPEN program, like UARS, as been unreasonably delayed. Plans for OPEN have been in a high state of readiness for a number of years and, in my opinion, represent the best aspects of this nation's leadership in magnetospheric and space plasma physics. The search for international partners has meant delays, often at the expense of

seeing important university research groups shrinking in intellectual and experimental capability. Part of the reason for the delays, of course, is the cost of mounting a multi-spacecraft mission. However, it must be realized that the physical phenomena being studies are extremely complex in both space and time, and that multiple observations are required to probe the full range of processes involved. The scientific activities involved with OPEN are at the forefront of scientific endeavour, balancing a measure of theoretical understanding of plasma physics against the true behavior of plasmas in nature. When measured against the scientific yields of other programs, it is clear that the OPEN is a first rate program serving the needs of a well developed scientific community. The results will be certain to bring further maturity to the disciplines of plasma physics and geophysics.

Against this backdrop, it is my opinion that the OPEN program deserves more funding and congressional backing than it has received in the past. The new international flavor brought about recently has come at the price of significantly reducing U.S. scientific participation.

Mr. VOLKMER. Thank you very much, Dr. Banks.

Let's begin first with Dr. Coleman on some of the questions on some of the recommended increases in augmentation in the budget in certain areas.

What would you estimate the current outlay for university capital equipment or instrumentation through NASA this year, let us say, the 1984?

Dr. COLEMAN. Well, that is a difficult one to measure. It turns out that one of the things that we have been able to do is obtain what might be considered capital equipment in the form of ground support or checkout equipment for our experiments. So there is capital-class equipment being purchased in the flight programs from time to time. My guess is that it would be altogether well under 5 percent, and I think the basic laboratory kind of equipment that we are talking about under a program such as this, which would not be tied to flight programs, in that category maybe 1 or 2 percent. I think 5 percent, if you look at an industrial organization that tries to maintain its level of productivity and so on, 5 to 10 percent is a pretty reasonable figure.

Mr. VOLKMER. Are you saying 5 percent of the R&A total?

Dr. COLEMAN. It's actually, I think, 5 percent of the total money that goes to the universities.

Mr. VOLKMER. The universities. All right.

Dr. COLEMAN. Including the money that goes to universities in the flight program.

Mr. VOLKMER. All right.

Dr. COLEMAN. And that is what's represented in this.

Mr. VOLKMER. About 150, isn't it? That would be about 7.5.

Dr. COLEMAN. I should add that that's really a guess.

Mr. VOLKMER. I understand that. We will probably check that out with NASA itself and see what they can give us on it.

Dr. COLEMAN. Yes.

Mr. VOLKMER. About how much of research and analysis line items; in other words, in planetary we have research and analysis in physics and astronomy, we have research and analysis right

down the line. We have that, and about how much of that would you say ends up for university support? Some, of course, goes to labs, some of it goes in-house.

Dr. COLEMAN. I can answer, I guess, based on my own lab. I would guess it's 1 percent.

Mr. VOLKMER. All right.

Dr. COLEMAN. That's the last 10 years. We are still living on equipment that we got during the Apollo program.

Mr. VOLKMER. All right.

Dr. COLEMAN. So this is—the issue that we are faced with now is a result of something like 10 to 20 years—I think it began even earlier in some of the other disciplines that are not space-related, some of the other university-based research activities supported by NSF, for example—NASA, because of the phasing. I think those of us who are doing space-related R&D are actually better off than some of our colleagues.

Dr. BANKS. Mr. Chairman, if I could be permitted to comment.

Mr. VOLKMER. All right.

Dr. BANKS. At Stanford we face exactly the same problem. I have a laboratory of approximately 100 professionals, and I would say the commitment to capital equipment from NASA is certainly less than 1 percent of our activities. The typical lifetime for computers and other advanced electronic equipment is less than 4 to 5 years, and the capital inventory of equipment required is probably on the order of $3 million or $4 million. It is virtually all out of date. We have no means for automated data-taking in laboratory experiments. We have had to look to gifts and flight ground support equipment to put in general facilities for the support of space research in our areas.

It is extremely difficult to get any money to provide for capitalization of ongoing research. There is simply no provision in the budget for that.

Mr. VOLKMER. Now, of course, we are running up here to the problem of, you know, these huge deficits, and anytime you try to add, you know, you run into problems.

Let us assume first that—and I do not know if you had an opportunity to look at the whole NASA budget, and I asked this other question; I know it may not be fair, but you can always go back and say, "Well, I have not had time to look at it," if you want to. But where do we find the money, you know, to put over here from where, as just an add-on feature? Do you have any ideas where we can reprogram it from?

Dr. COLEMAN. Well, if we're talking about the capital equipment item in particular, I would like to see it considered as an add-on feature. I think the needs can be mitigated to some extent if we had different ways to handle cash flow problems. One of the difficulties in our business is, the way we handle capital equipment, it's a kind of a this-year purchase, and we up until recently, for example, were not allowed to cover the cost of money with grant funds, so the kinds of cash flow management processes that are used in business were not available to us. We had to buy it all out of money this year.

So there could be some help in the smoothing process. I think that there are economies that could be realized in other areas, but

I have not gone through the budget with the idea of finding a line item or a chunk of one that could be done in place of this. I really think it's important to view it as an actual augmentation for the R&D community.

Mr. VOLKMER. Now let us assume, though, that there is 5 percent. As I understand the testimony, if I remember right, from Dr. Edelson on Tuesday, they estimated there is approximately total university money in the total NASA budget, approximately $178 million. Now if we assume that 5 percent that is equipment, we are close to $9 million right there, $8.9 million or something like that.

Dr. COLEMAN. That's right. But a lot of that, that total, for one thing, includes the money from flight programs that goes to universities; and second, that 5 percent includes the kinds of equipment that Dr. Banks and I mentioned earlier that is tied to a flight program, sometimes it is of general utility, but often not. What we are after here is the fundamental basic laboratory equipment in data handling for electronics labs for data processing and things of that sort that is essentially the underpinning of any modern laboratory.

Mr. VOLKMER. Would you be so kind as to give us a list of the type of equipment we are talking about in the line-item area? You do not have to do it right now, but I would like for you to furnish that to the staff if you would within the next week if you could do that.

Dr. COLEMAN. Surely.

[Refer to Question 1 of *Additional Questions for Dr. Coleman.*]

Dr. BANKS. Mr. Chairman, could I comment? You asked Dr. Coleman where would this money come from?

Mr. VOLKMER. Yes.

Dr. BANKS. In my observation, there are two areas that NASA is actively pursuing which could be regarded as sources. The organization of the groups outside the Office of Space Science and Application certainly could be tapped to divert portions of money now given to industrial support, to divert a small portion of that into university-related study institutes and general base programs.

I myself have done this, most recently through the Office of Technology, Aeronautics and Space Technology, with the Center for Aeronautics and Space Information Sciences. Small amounts of money coming as grants to universities have large impact.

Second, the centers themselves should be encouraged to support more strongly their relationship with the universities. In the past, certain centers have had contractual flight-related types of programs, but not the general support programs that universities are seeking at the present time. Both of those offer diversionary capability in addition to the add-on that Dr. Coleman mentioned.

Dr. COLEMAN. In response to your question about the kinds of equipment, I think one thing you might do is get the list of the kinds of equipment that was requested in response to that DOD program. There is a very, very extensive list available, and I think our needs are basically the same as theirs are.

Mr. VOLKMER. As long as they have a list, we do not have to go through the 100 applications.

[General laughter.]

Dr. COLEMAN. That's right. No, they should have a list, and I think we have been looking into this with the idea of trying to

come up with ways to finance these things with commercial paper of some kind. So I am quite sure the list is available, and I think the needs of laboratories for space-related R&D are very similar to those across the board. These are the generic tools for modern research.

Mr. VOLKMER. When you talk about—so I understand it, because I do not right now—when you talk about equipment for flight operations or things like that, what are we talking about? What types of flights, to begin with? Are we talking about soundings? Are we talking about shuttle flights? Are we talking about planetary?

Dr. COLEMAN. Across the board. Dr. Banks and I are——

Mr. VOLKMER. In other words, if you have the research going on into a certain area, then you furnish the equipment to go specifically with that?

Dr. BANKS. That's correct.

Mr. VOLKMER. That would be specifically oriented equipment for that then?

Dr. COLEMAN. Oftentimes it goes into a package that you deliver to the center. It stays on the ground, but it's part of the experiment——

Mr. VOLKMER. Right.

Dr. COLEMAN [continuing]. For checkout and testing and things of that sort, and there may be a minicomputer in there that you'd love to have for your laboratory for general purpose laboratory equipment.

Mr. VOLKMER. All right.

Dr. BANKS. There is a—excuse me—tremendous need for computer-related equipment at the present time. It's new technology, new displays; the computer networking that Dr. Coleman mentioned requires the computerization of entire laboratories and using computers as information systems rather than as something just to calculate and to do scientific calculations with.

Graphical displays, the goal is increasing productivity of scientists and students that are working in universities, and the cost for even a medium-size facility for a laboratory of the type that Dr. Coleman sees at UCLA is on the order of $1.5 million. That money simply is not available. Even though you may have 10 or 15 large flight contracts and grants in a particular institution, there is no way of tapping into a fraction of each of them to put into a general facility.

Mr. VOLKMER. All right. Now you discussed a little bit about the OPEN program. Is that now known as the ISTP program?

Dr. COLEMAN. That's correct.

Mr. VOLKMER. You are stating that you feel that at last year's summit meeting at Williamsburg there was a commitment basically to that?

Dr. COLEMAN. I don't think it's a legal or contractual commitment at this point. What happened is that the international flavor of the thing changed, the degree of internationalization of the project changed dramatically after the meeting. It was, in part, a response to the obvious budgetary pressures. It was a way to get a program done with the help of the international community that we might not be able to afford otherwise.

But in the subsequent negotiations, which are going very well, we are getting closer and closer to what amounts to a commitment, and, in fact, I think we are really there, even though there may not be the papers signed. We are going to have to do our part, or we are going to be right back in the same situation in which we were with ISPM. We just can't keep doing that if we're going to rely on international collaboration to do research.

Mr. VOLKMER. You are saying that we need approximately $6 million?

Dr. COLEMAN. Yes.

Mr. VOLKMER. To handle that?

Dr. COLEMAN. That's right. Otherwise, it will—because I do believe NASA is aware, I am sure they are aware, of the importance of these international relations—they will find the money somewhere, and it will come out of the research and analysis part of the budget, which is, as I said, the backbone of what we do in our labs in our graduate student research programs.

Mr. VOLKMER. Let us assume that we do not have any additional for the planetary research and analysis budget. Can you give us some idea of the type of things that will not be able to be done with the actual reduction that we have in that line item?

Dr. COLEMAN. I will refer to my notes because——

Mr. VOLKMER. All right.

Dr. COLEMAN [continuing]. I put a list of things down.

Mr. VOLKMER. All right.

Dr. COLEMAN. I hope they are all in here, but I can—let me start from memory while I fish through these——

Mr. VOLKMER. All right.

Dr. COLEMAN [continuing]. In this stack of papers.

There is the advanced—I think the advanced development for some of the missions is an important component that wouldn't be supported. I think there are something, several hundred. One of the things that was pointed out to me is that the average grant in the planetary R&A program is $60,000 a year. We're talking about several hundred principal investigators' programs on campuses that would be, that are, in jeopardy in this situation. This, I think, has been recognized early on. You folks, the Congress, has tried to do something about it, and has succeeded in doing something about it, and so the program has gone along—in fact, gotten stronger in the last year or so. Now, with this setback that is established by the 1985 budget, we would undo a lot of that sort of thing. And the kinds of dollars, if you just assume it's a zero-sum situation, you're talking about taking it out of R&A because we are, after all, going down the road to these new starts.

There is, I think, a more specific statement of what we would do with it. It would provide for continued analysis of Pioneer and Venus and Voyager data, instrument development for the new start for the Mars geochemical and climatology Orbiter mission, future development for a future comet rendezvous mission, and scientific support for the U.S. people who participate in ISPM, continued development of the Mariner Mark II technology, which is one of the very major, one of the major components of the newly structured planetary exploration program, the sort of intermediate, as you know, the three-axis stabilized component of that spacecraft

project, some upgrading of laboratory facilities, continued support for low-cost experiments on current flight opportunities for which there is no other current source of support.

But the amounts involved, as I say, are those that correspond to the annual grant level for several hundred of the PI's, and I think there are some 600 principal investigators in that program now, supported under the R&A and ATD part of the budget.

Mr. VOLKMER. Now to go a little bit to the microgravity, what we used to know as the materials processing.

Dr. COLEMAN. Materials processing.

Mr. VOLKMER. We had testimony last Tuesday. Some of us have been interested in trying to get the Centers for Excellence started, especially in the areas of the organics. We have found out from NASA that they hope to have the thing all ready and announcements on Centers by sometime this summer. Undoubtedly, some of the money that is in the R&A there is going to go to that.

You have recommended an additional increase in that of approximately $10 million. What, in addition to the Centers, would that $10 million be used for?

Dr. COLEMAN. Well, that's so far from my field that I am not sure I can give you an informed answer. You heard the testimony in your special session last September about where the program was going and so on. The reason that I suggested as I did this augmentation is really based upon a feeling that I have developed about the way that community is developing, the quality of the people coming into it, the kinds of things being proposed.

For a person like myself who is not an expert in the field, I kind of base my feeling for a program like this on the people that are in it. And all of those trends are very positive, and the space shuttle capacity for doing these things is there, and I think that it's such an important component of both the basic research for the agencies and industry and the commercialization aspect and then adding to it the space station thrust, that it just has to be done.

But I must say I cannot be more specific. I have a list of things that were discussed, but I couldn't really comment on the details of the experiments.

[Refer to Question 3 of *Additional Questions for Dr. Coleman.*]

Mr. VOLKMER. Now, you mentioned the Hitchhiker program, the Spartan program and efforts to get on there. Can you give us any idea as to what you feel that we as people in the Congress who feel basically the same way you do that it should be easier and quicker to be able to get there? If we are going to replace the sounding rockets and the balloons with more time spent on the shuttle, then we ought to be able to utilize it, or you ought to, anyway. So if you have got any ideas, even if not now, later, I would like to know what they are.

Dr. BANKS. That's a tough one.

[Refer to Question 5 of *Additional Questions for Dr. Coleman.*]

Mr. VOLKMER. How can we get around some of the redtape?

Dr. COLEMAN. I raise it because I think if we continue to discuss it, there's hope of making some progress. I think in the past on a couple of occasions NASA has really tried to do something about it, but there is a great concern as you go through the system that people say, "Yes, we'll go along with a failure, and so don't worry

about doing all this 100 percent kind of qualification," but then when the failure occurs, they don't react that way. And so there is a tremendous pressure among the people who have to do the work that feel that they're on the line to have things 100 percent. And the net result is we have spacecraft that have a 2-year mission that lasts for 20 years and no one ever goes back and says, "Gee, how much money did we spend doing this that we didn't have to spend? Maybe we're overkilling it."

It's built into the system, and it's very difficult to do anything about. We just have to keep trying.

Mr. VOLKMER. One last thing, and then I would like to get on to Dr. Banks on the other subjects a little bit.

Dr. BANKS. If you want another comment on the Spartan—

Mr. VOLKMER. Yes.

Dr. BANKS. I am actually participating in a Spartan project and can give you more detail.

Mr. VOLKMER. Fine. I would like to know exactly how—

Dr. BANKS. We have an experiment that we flew on a rocket from White Sands last summer and had a technical difficulty. It was a joint Japanese-United States rocket. We are now discussing with Marshall the flight of that off the space shuttle for a period of 3 days.

As you know, there is a tendency towards these large monolithic programs for very high-quality big instruments, and this tends to leave out the smaller university-oriented research and introduces a need for large-center mission support activities. I think therein lies part of the difficulty and the real hope of the Spartan program of taking elements of the former suborbital program, the rockets and balloon programs, taking instruments that can be upgraded into the much harsher space environment, letting them be deployed and then retrieved from the orbiter.

The difficulty and the costs, though, aren't insignificant. It isn't just like flying a rocket, because you must face a full integration with the space shuttle mission planning activity. You have to coordinate the activities of the mission specialists or the crew, as the case may be; and furthermore, the shuttle itself does not have the capability for transmitting data back and forth from the subsatellite. And it just is not rocket technology or an H-P calculator flown in space. You have to spend the money to do it, and because of other priorities, that money and the encouragement to do that sort of activity just has not been there.

But you're seeing the beginning of a program that has true promise for sort of the glue of space research, the smaller projects that train the students, that bring in first-class science and fit in between the very larger solar telescopes and space telescopes and so forth.

So there is a great deal of hope, and I think anything the Congress can do to encourage NASA, even small changes in that would have enormous impact on the fundamental types of space research that can be done from the shuttle. Not everything can be done from the shuttle.

Mr. VOLKMER. Now one of the last things that, as I said, I would like to get to is that what you seem to be proposing, Dr. Coleman, and I am sure some of the other university people would propose, is

that, especially on the equipment item, that we put a single line item in the budget somewhere for NASA in the authorization bill, saying there is going to be $11 million or some figure for equipment, and then perhaps in the report we would say what types of equipment to delineate from that which you are already basically getting for flights.

The question I have is, are we now saying that NASA as well as NSF—because NSF does basically provide equipment, et cetera, for research—that NASA should join in with NSF for that?

Dr. COLEMAN. Yes. I think the two components of the program that are going now are Department of Defense and NSF, and basically they're both slanted toward universities. Only universities can apply for the DOD support. I think the Department of Energy is moving in that direction. There is a strong emphasis on university relations in the DOE, coming from the Secretary. And I think NASA should do the same. Exactly what the mechanism would be, I don't know, but I think that something of that sort at least for a while, because we have got to undo the damage that's been done and make sure that we don't fall into this pit again. And that means that we probably will have to do something like this over the short term.

Over the longer term, if we could simply build into our fiscal process apportionment of a reasonable amount of money for capital equipment as a requirement, if you will, that we prudently budget and distribute our money, including not letting everything rot, we may be able to do away with this kind of special category.

[Refer to Question 8 of *Additional Questions for Dr. Coleman.*]

Mr. VOLKMER. Dr. Banks, as I understand the structure of your task force, it will be that you will report to the Space and Earth Sciences Committee. Is that correct?

Dr. BANKS. I will be a member of that committee, and my reports, as I understand the chain of command, would go in that direction.

Mr. VOLKMER. And then they would have to be assimilated or approved or reviewed and then proceed onward?

Dr. BANKS. Mr. Edelson sits on that committee himself. It's an advisory committee to him. And by virtue of sitting on that, I would feel that I would have direct access to his ear.

Mr. VOLKMER. All right. But you are going to have to go through Dr. Edelson. Is there any input to a man named John Hodge on that task force?

Dr. BANKS. John and I will be together in 2 weeks. Yes, we are in communication both with John and with the rest of his staff. I think there is a very great appreciation by them of the importance of our committee, and it is a very synergistic thing. We don't want them to do things that aren't beneficial to the scientific community, and they are very clearly worried about things that we would say that would be harmful to their project.

Mr. VOLKMER. Well, as one who believes that we should have a space station, I would like to give you this. I have been reading some of the remarks from some of the scientists who have reservations about the space station, and understanding that, I can appreciate some of their concerns, such things as money would be taken away in the budget from other things, including university support

and planetary and everything down the line to anything that is for earth orbiter and that area goes on the space station, it does not go up over here maybe where it should be.

Do you feel that it is part of your job to make sure that those areas are covered and those concerns are taken care of?

Dr. BANKS. Well, very definitely, one of the tasks given to us was to assess the overall program. And I don't know if it's possible to build a fence around the space station in the economic sense, but we know what the danger is. Perhaps the best thing to say is the space shuttle has been a warning to us all of what can happen, and we have to be very sensitive to the needs of planetary exploration and other types of science that simply don't use that type of platform.

For that reason, on the committee I intend to appoint people representing those disciplines. It's not a utility-base advisory committee, but a broad scientific and applications committee.

Mr. VOLKMER. All right. Then the other thing that has come to my attention just through these hearings are such things as the shuttle infrared telescope operation. It is now not shuttle anymore, because the IRAs has shown us that we can get the cyrogenics there and that they can last for periods of time, so now they are starting to say,

> Well, we will call it the space, and we will make it a freeflyer and do it that way, but we are going to have to take it back and look at it because of that to redesign it, et cetera.

Then you hear that by the time that gets done, they will say, "Hey, we can put it on the space station. Now let's redesign it again."

Now do you see some of it?

Dr. BANKS. Well, I can give you my personal feeling about this. I am very much aware of this; that is, that any of these programs shouldn't be viewed in terms of a monolithic final product, that if you are still doing that type of observation, you need what are called principal investigator class experiments from universities or other groups. These with experience become larger and more focused in their direction and culminate in activities.

But to say that there is one shuttle infrared telescope and we won't do anything else clearly leads you into this type of difficulty——

Mr. VOLKMER. I see.

Dr. BANKS [continuing]. And scientific procrastination of that type. And it clearly should not happen.

Mr. VOLKMER. Dr. Coleman, do you wish to comment on any of this?

Dr. COLEMAN. Well, I was more interested in commenting about the fence business around the space station.

Mr. VOLKMER. All right.

Dr. COLEMAN. But behind you is the other example. We have had a tough time with space shuttle, but with the Apollo program I think it went the other way. So there is a precedent for having a major program within the agency, and I was at that time working both on Apollo and in the planetary program and in the earth or-

biting program, and those programs were maintained and, in fact, strengthened through that era. So it can be done.

Mr. VOLKMER. But the whole space program, the whole NASA budget, at that time was a lot larger in comparison to our total budget than it is now. We are at less than 1 percent right now.

Dr. COLEMAN. It's true.

Mr. VOLKMER. There were periods there you were about 2 percent.

Dr. COLEMAN. Yes. That's true.

Dr. BANKS. What truly concerns me as we go from the Shuttle into the space station is the reliance on singular large instruments that are intended to serve an entire community, because all of your marbles are being put into one small packet. And yet—perhaps this sounds like motherhood—but all of the scientists who are participating do come from the universities and have to have exposure to the experimental techniques and equipment and ideas that lead them on to be professional scientists.

If you don't give them the flight opportunities that Dr. Coleman mentioned, if you force them to leave the universities to go to specialized centers, I think you are attacking the very structure of education of space scientists in this Nation. It's very difficult.

Mr. VOLKMER. All right.

I just wanted to thank both of you for being here today. You have been very helpful. I do want to comment, Dr. Banks, that as I have said, I do have some of those same reservations as the others, and I will look forward to hearing from you as we go along, assuming that we do authorize and we do have the money put in for the space station and we do get a start on it, to make sure that these concerns are taken care of and that we do not have to put a fence around the space station. But we do not want it also to gobble up everything else on its way.

Dr. BANKS. Yes.

Mr. VOLKMER. I am sure that the committee feels the same way on my concerns, in talking with them.

So that will conclude this part of it. We will now go to Dr. John A. Eddy, chairman of the Committee for the International Geosphere/Biosphere program, to talk to us about something a little bit different, and we will see where NASA can contribute to the international geosphere/biosphere program. Hopefully, we do not start to pull out of that, too.

STATEMENT OF DR. JOHN A. EDDY, CHAIRMAN, COMMITTEE ON THE INTERNATIONAL GEOSPHERE/BIOSPHERE PROGRAM, NATIONAL ACADEMY OF SCIENCES

Dr. EDDY. Mr. Chairman and members of the subcommittee, I thank you for the opportunity to meet with you today on behalf of the National Academy of Sciences' Committee on the International Geosphere/Biosphere Program. That committee has just been formed and has not yet met. What I present today are my own views. But it is a chance for me to explain a new program whose ultimate success will depend critically on the leadership of this Nation and on the support of NASA and other U.S. scientific agencies.

The IGBP is a bold concept now taking form to bind certain efforts of the Earth and biological sciences together to wield a well-organized international attack on common problems of global scale.

An example of such a problem, emphasized in a number of earlier Academy and agency studies, is that of the worldwide increase in carbon dioxide and its implications for the future.

As you know, a marked increase in the world atmospheric content of CO_2 is now well documented: a measured rise of about 15 percent since preindustrial times in this most important greenhouse gas.

The apparent cause is our burning of fossil fuels and the large-scale clearing of forests. In this decade atmospheric carbon dioxide will rise another 3 percent, and more in the 1990's, for the increase is almost inexorably accelerating.

The response of the biosphere to such a major change is less certain, as is the eventual impact on climate and on polar ice and on ocean levels. It will almost certainly cause a warming of the Earth within the lifetime of our children, if not our own. But the amount of that warming is still debated. At one extreme, carbon dioxide warming could force the largest change in the surface temperature of the Earth since the end of the last ice age 10,000 years ago, with significant impacts on agriculture, shorelines, and certainly world economy. Or the warming could be small and barely noted in the normal short-term excursions of weather.

The large uncertainties in this global weather forecast stem in part from the unknown role of plant life and of the oceans in responding to the increase, as well as the natural variations in the abundance of this trace gas in the past.

It also depends upon the contribution of other greenhouse gases, such as methane, that are also rising and also intimately linked to the biosphere.

Faced with the most serious prediction he has ever been asked to make, the climatologist faces an array of unknowns that involve not only other disciplines, but the interplay of all of them.

I could cite a number of other fundamental problems equally global in nature and equally multidisciplinary. None is the private concern of any one country or the exclusive province of a specific field of study. As with the carbon dioxide issue, such problems transcend not only national boundaries, but the equally fixed bounds of organized scientific disciplines, such as meteorology, oceanography, geology, or biology.

For these reasons, we have been slow in science to come to grips with them or to tackle global problems in the holistic way that is surely demanded for their ultimate solution. This is the gap that an IGBP might bridge.

A quarter of a century ago, a more limited effort was mounted that enlisted multinational collaboration on problems specific to the atmosphere, the oceans, the polar regions, the solid Earth, and the Sun. The International Geophysical Year was inspired by a bright dawn of new technology. It was launched largely through the scientific leadership of this country. Its precedent was an earlier venture, equally bold for its time, the International Polar Year of 1882 and 1883. But the geographic coverage of the IGY embraced

the whole world from pole to pole. Seventy-eight countries took part in it. About 20,000 scientists and observers were involved.

The IGY lasted 2½ years, ending in 1959, but its impact on the course of science far exceeded its original goals of global measurement. Through the IGY, less developed countries were made dignified partners in research by contributing needed pieces in global data networks. The IGY had an influence equally great in science education, the development of new instruments, and on the ensuing course of international cooperation in research in many fields. It stands today as the most remarkable example in history of unfettered international cooperation, undisturbed by any political ideology.

In the past year, the first steps were taken in this country and abroad to explore the potential of another such program, in some ways similar to the IGY, but in others, vastly different and farther-reaching. It has grown from a proposal made by Dr. Herbert Friedman to the National Research Council about 1 year ago.

The program now envisioned would concern not only the physical environment of Earth, but all of life on it as well, the living biosphere. Such emphasis comes from an appreciation that plant and animal life in the biosphere are very much involved, for example, in the chemistry of the atmosphere, and that man is very much an agent in altering not only the atmosphere, but the oceans and the form and chemical composition of the crust of the Earth as well. These connections go both ways. They are interrelated and interdependent.

The international geosphere/biosphere program [IGBP], as it is tentatively known, would focus on a number of broad, but well-defined, multidisciplinary problems. It would embrace all of the sciences that deal with the Earth and all manner of life on it, extending from the Sun to the mantle and to the bottom of the seas. Its aim would be to marshall the collective efforts of many nations to understand a number of specific global problems and to trace the linkages that are known but now uncharted that connect the atmosphere, the biosphere, the lithosphere, oceans, and Sun-Earth space.

It is based on the concept that global problems require global participation. The IGBP does not exist today. But it is on the horizon and in the minds of leading scientists in all the fields that I have mentioned. For the United States, it looms as an opportunity to exert an influence in an endeavor that promises to benefit all the world, a chance to demonstrate leadership in a venture of science and technology that is both practical and profound. It might also help counter our reputation as unfeeling exploiters of the limited resources of the planet on which we live.

A program of such a scale might be organized in time to begin in about 1990, and last perhaps a decade. The geosphere/biosphere program will be discussed at the general assembly of the International Council of Scientific Unions in Ottawa in September of this year by our own representatives and those of other nations.

China, to mention only one, has taken an active interest in preliminary planning. It seems likely that it will be favorably endorsed by international representatives of various disciplines, and that by 1987 more concrete plans will have taken form.

Such an ambitious program would not be possible were it not for the modern vantage of space and the potential of monitoring the environments of Earth and life upon it from an elevated, orbital perspective. This includes the physical and chemical properties of the oceans, the mineral composition of the hard Earth, the dynamics and chemical composition of the atmosphere, the influence of the Sun upon the Earth and near-Earth space, and the monitoring of plant and animal life on the land and in the oceans. Prior programs of the National Aeronautics and Space Administration have demonstrated both the feasibility and the power of every one of these. The science of oceanography, for example, has literally been revolutionized by Seasat and Nimbus 7.

There are few precedents for such a wide-reaching, interdisciplinary effort. We cannot anticipate at this time what fraction of the restricted resources of world science or scientists need be involved. It will be strongest, I think, if it is limited to a restricted set of well-defined problems that are certain to benefit from multidisciplinary attack and international emphasis. The scientific priorities of today in the fields involved are different and more sophisticated than those of 1957: problems are more keenly debated and more sharply defined.

Nor is the IGBP seen as an umbrella for all science in all fields or a preemptor of other effective national or international programs in any of the disciplines involved. It would be a mistake for such a program, however well planned or intended, to sap the strength of other promising disciplinary programs, such as the world climate program, or the world ocean circulation experiment.

No great increase in funding for work in this area need be sought immediately. If it comes to pass, it will have an effect, in part through pressures to plan and coordinate certain disciplinary and national programs for maximum scientific gains. Eventually, the development of a more coherent program in broad problems of the sort I have described will prove more cost effective.

It seems obvious that NASA's program of Earth sciences and applications would be a key player in any IGBP, however envisioned. In the fiscal year 1985 budget request now before us is a commendable new step in this very direction: a new allocation of $1 million in the Office of Space Science and Applications for interdisciplinary research and analysis. It reflects NASA's own endorsement of a global program to understand biogeochemical cycles through eventual, down-looking measurements from Earth orbit.

The overlap of that program with the broader IGBP is extensive, and some of its architects serve on the U.S. IGBP Committee. The NASA program in biogeochemical cycles focuses on some of the same interactions of atmosphere and oceans and biosphere that I have mentioned here. We all hope that in time these two programs will be woven together in a common fabric to accomplish common goals.

A necessary piece of that fabric, by the way, is the further understanding of the role of the Sun in the web of connections that I have been describing. For this reason, the domain of an IGBP begins not high in the stratosphere or in the ionosphere, but at the Sun itself, the origin of almost all the energy of the atmosphere and the oceans, and the without-which-not of life on Earth.

We live in the outer atmosphere of the Sun and depend utterly on its constancy. There is no question that the Sun varies, or that solar changes affect the Earth. But the full extent of these effects cannot be known until we can follow the course of solar perturbations step by step from Sun to Earth, in dedicated programs of global measurements that could well be a part of an IGBP.

The House Committee on Science and Technology endorsed similar thoughts last year in authorizing in the fiscal year 1984 NASA budget a specific study of Sun-Earth interaction, and calling for a more organized and more holistic approach to this sometimes orphaned field of study.

Last month, in an address before the American Astronomical Society, Dr. Keyworth sounded a similar call for new attention to what he called the lagging field of solar-terrestrial research. As he pointed out, that field may have suffered in emphasis or funding because it lacks the perceived glamor of astronomy or planetary science. Or perhaps because it is too often looked upon as applications and not science.

In the broader scope of understanding the Earth as a system, these labels have no distinction. Of all the planets, the Earth still presents the greatest scientific puzzle and offers the largest reward for their solution. It is surely time to recognize that science is served as well by looking down at our planet as by looking up and away from it, and with equal intellectual challenge.

Mr. Chairman, this concludes my formal prepared statement. But I am happy to respond to any questions.

[The prepared statement, plus answers to additional questions asked of Dr. Eddy follow:]

PREPARED STATEMENT OF JOHN A. EDDY, CHAIRMAN, COMMITTEE FOR THE INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAM, NATIONAL ACADEMY OF SCIENCES

Mr. Chairman and Members of the Subcommittee: I thank you for the opportunity to meet with you today on behalf of the National Academy of Sciences Committee on the International Geosphere-Biosphere Program. That committee has just been formed and has not yet met; what I present today are my own views. But it is a chance for me to explain a new program whose ultimate success will depend critically on the leadership of this nation and on the support of NASA and other U.S. scientific agencies.

The IGBP is a bold concept now taking form to bind certain efforts of the Earth and Biological Sciences together to wield a well organized, international attack on common problems of global scale. An example of such a problem, emphasized in a number of earlier Academy and Agency studies, is that of the worldwide increase in carbon dioxide and its implications for the future.

As you know, a marked increase in the world, atmospheric content of CO_2 is now well documented: a measured rise of about 15% since pre-industrial times in this most important "greenhouse gas". The apparent cause is our burning of fossil fuels and the large-scale clearing of forests. In this decade atmospheric carbon dioxide will rise another 3%, and more in the 1990's, for the increase is almost inexorably accelerating. The response of the biosphere to such a major change is less certain, as is the eventual impact on climate and on polar ice and ocean levels. It will almost certainly cause a warming of the Earth within the lifetime of our children, if not in our own, but the amount of that warming is still debated. At one extreme, carbon dioxide warming could force the largest change in the surface temperature of the

Earth since the end of the last Ice Age, 10,000 years ago, with significant impacts on agriculture, shorelines, and certainly world economy. Or the warming could be small and barely noted in the normal short-term excursions of weather.

The large uncertainties in this global weather forecast stem in part from the unknown role of plant life and of the oceans in responding to the increase, as well as the natural variations in the abundance of this trace gas in the past. It also depends on the contribution of other greenhouse gases, such as methane, that are also rising and also intimately linked to the biosphere. Faced with the most serious prediction he has ever been asked to make, the climatologist faces an array of unknowns that involve not only other disciplines, but the interplay of all of them.

I could cite a number of other, fundamental problems equally global in nature and equally multidisciplinary. None is the private concern of any one country or the exclusive province of a specific field of study. As with the carbon dioxide issue, such problems transcend not only national boundaries, but the equally fixed bounds of organized scientific disciplines, such as meteorology, oceanography, geology, or biology. For these reasons we have been slow in science to come to grips with them or to tackle global problems in the holistic way that is surely demanded for their ultimate solution. This is this gap that an IGBP might bridge.

A quarter-century ago, a more limited effort was mounted that enlisted multinational collaboration on problems specific to the atmosphere, the oceans, the polar regions and solid Earth, and the Sun. The

International Geophysical Year was inspired by the bright dawn of new technology --- electronic instruments, scientific balloons and rockets and space probes, and the first automatic computers capable of handling data on a global scale. It was launched largely though the scientific leadership of this country. Its precedent was an earlier venture, equally bold for its time: the International Polar Year of 1882-1883. But the geographic coverage of the IGY embraced the whole world, from pole to pole; seventy-eight countries took part in it--- representing most of the community of nations at the time. About 20,000 scientists and observers were involved.

The IGY lasted two and one half years, ending in 1959. But its impact on the course of science far exceeded its original goals of global measurements. Through the IGY less developed countries were made dignified partners in research by contributing needed pieces in global data networks. The IGY had an influence equally great in science education, the development of new instruments, and on the ensuing course of international cooperation in research in many fields. It stands today as the most remarkable example in history of unfettered international cooperation, undisturbed by political ideology.

In the past year the first steps were taken in this country and abroad to explore the potential of another such program: in some ways similar to the IGY but in others vastly different and farther reaching. It has grown from a proposal made by Dr. Herbert Friedman to the National Research Council about one year ago. The program now envisioned would concern not only the physical environment of Earth, but all of life on it as well: the living biosphere. Such emphasis comes

from an appreciation that plant and animal life in the biosphere are very much involved, for example, in the chemistry of the atmosphere and that man is very much an agent in altering not only the atmosphere but the oceans and the form and chemical composition of the crust of the Earth as well. These connections go both ways; they are interrelated and interdependent.

The International Geosphere-Biosphere Program, as it is tentatively known, would focus on a number of broad but well-defined multidisciplinary problems. It would embrace all of the sciences that deal with the Earth and all manner of life on it, extending from the Sun to the mantle of the Earth, and to the bottom of the seas. Its aim would be to marshal the collective efforts of many nations to understand a number of specific, global problems, and to trace the linkages, known but now uncharted, that connect the atmosphere, the biosphere, the lithosphere, oceans, and Sun-Earth space. It is based on the concept that global problems require global participation.

The IGBP does not exist today. But it is on the horizon and in the minds of leading scientists in all the fields that I have mentioned. For the United States it looms as an opportunity to exert an influence in an endeavor that promises to benefit all the world: a chance to demonstrate leadership in a venture of science and technology that is both practical and profound. It might also help counter our reputation as unfeeling exploiters of the limited resources of the planet on which we live.

A program of such a scale might be organized in time to begin in about 1990, and last perhaps a decade. The Geosphere-Biosphere Program

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will be discussed at the General Assembly of the International Council of Scientific Unions in Ottawa in October of this year by our own representatives and those of other nations. China, to mention only one, has taken an active interest in preliminary planning. It seems likely that it will be favorably endorsed by international representatives of various disciplines, and that by 1987 more concrete plans will have taken form.

Such an ambitious program would not be possible were it not for the modern vantage of space, and the potential of monitoring the environments of Earth and life upon it from an elevated, orbital perspective. This includes the physical and chemical properties of the oceans, the mineral composition of the hard Earth, the dynamics and chemical composition of the atmosphere, the influence of the Sun on the Earth and near-Earth space, and the monitoring of plant and animal life on the land and in the oceans. Prior programs of the National Aeronautics and Space Administration have demonstrated both the feasibility and the power of every one of these. The science of oceanography, for example, has literally been revolutionized by SeaSat and Nimbus 7.

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Nor is the IGBP seen as an "umbrella" for all science in all fields or a pre-emptor of other effective national or international programs in any of the disciplines involved. It would be a mistake for such a program, however well planned or intended, to sap the strength of other promising disciplinary programs, such as the World Climate Program, or the World Ocean Circulation Experiment.

No great increase in funding for work in this area need be sought immediately. If it comes to pass it will have an effect, in part through pressures to plan and coordinate certain disciplinary and national programs for maximum scientific gain. Eventually the development of a more coherent program in broad problems of the sort I have described will prove more cost effective.

It seems obvious that NASA's program of Earth Sciences and Applications would be a key player in any IGPB, however envisioned. In the FY1985 Budget Request now before us is a commendable new step in this very direction: a new allocation of 1 million dollars in the Office of Space Science and Applications for "Interdisciplinary Research and Analysis." It reflects NASA's own endorsement of a global program to understand biogeochemical cycles though eventual, down-looking measurements from Earth orbit. The overlap of that program with the broader IGBP is extensive and some of its architects serve on the U.S. IGBP Committee. The NASA program in biogeochemical cycles focuses on some of the same interactions of atmosphere and oceans and biosphere that I have mentioned here. We all hope that in time these two programs will be woven together in a common fabric to accomplish common goals.

A necessary piece of that fabric, by the way, is the further understanding of the role of the Sun in the web of connections that I have been describing. For this reason the domain of an IGBP begins not high in the stratosphere, or in the ionosphere, but at the Sun itself, the origin of almost all the energy of the atmosphere and the oceans, and the without-which-not of life on Earth. We live in the outer atmosphere of the Sun and depend utterly on its constancy. There is no question that the Sun varies, or that solar changes affect the Earth. But the full extent of these effects cannot be known until we can follow the course of solar perturbations step by step from Sun to Earth, in dedicated programs of global measurements that could well be a part of an IGBP. The House Committee on Science and Technology endorsed similar thoughts last year in authorizing in the FY1984 NASA budget a specific study of Sun-Earth Interaction, and calling for a more organized and holistic approach to this sometimes orphaned field of study. Last month, in an address before the American Astronomical Society, Dr. Keyworth sounded a similar call for new attention to what he called the lagging field of Solar-Terrestrial Research. As he pointed out, that field may have suffered in emphasis or funding because it lacks the perceived glamor of astronomy or planetary science. Or perhaps because it is too often looked upon as "applications" and not "science." In the broader scope of understanding the Earth as a system these labels have no distinction. Of all the planets, the Earth still presents the greatest scientific puzzles and offers the greatest rewards for their solution. It is surely time to recognize that science is served as well by looking down at our planet as by looking up and away from it, and with equal intellectual challenge.

Mr. Chairman, this concludes my prepared statement. I am happy to respond to any questions.

Dr. John A. Eddy is a Senior Scientist at the High Altitude Observatory , a laboratory of the National Center for Atmospheric Research in Boulder, Colorado. NCAR is sponsored by the National Science Foundation.

Dr. Eddy received his B.Sc. degree in 1953 from the U.S. Naval Academy and served as a line officer for four years. In 1962 he was granted a Ph.D. in AstroGeophysics from the University of Colorado. Since then he has worked as a solar astronomer at the High Altitude Observatory, as a fellow at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, and as a Professor Adjoint at the University of Colorado.

His research interests are the physics of the Sun and its influence on the Earth, and the history of solar behavior. His work has been instrumental in establishing the record of solar variability in the past through historical records and tree-ring radiocarbon amounts. In 1983 he received the James Arthur Prize from the Harvard-Smithsonian Center for Astrophysics for his research on the ancient Sun. He is the author of over 100 scientific papers and the author or editor of three books dealing with the Sun.

Dr. Eddy is the chairman of the Committee for the International Geosphere-Biosphere Program of the National Academy of Sciences and a member of the Academy Board on Atmospheric Sciences and Climate. He was the chairman of the Panel on Solar Variability, Weather, and Climate that completed a report on this subject for the National Research Council in 1982. Since 1979 he has served as U.S. Leader in a US/USSR scientific exchange program in the area of solar influences on climate, under the US/USSR Bilateral Treaty for the Protection of the Environment. He was the first chairman of the Historical Astronomy Division of the American Astronomical Society and the current Vice-President of the Commission on the History of Astronomy of the International Astronomical Union.

SUBCOMMITTEE ON SPACE SCIENCE & APPLICATIONS

Response to Additional Written Questions from the February 9, 1984, hearing at which Dr. John A. Eddy testified.

QUESTION 1:

Can you articulate some central objective of IGBP?

ANSWER:

The central objective of an IGBP is to focus international and multidisciplinary efforts to solve selected scientific problems of global scale, much as the International Geophysical Year of 1957-1959 enlisted scientists of many countries and diverse disciplines to increase our understanding of the Earth, the oceans, and the atmosphere. The target of an IGBP effort would be to understand processes of global change that ultimately effect life on Earth.

QUESTION 2:

What entity do you envision ought to be the international focal point for IGBP? The U.S. focal point?

ANSWER:

The international agency that will coordinate plans for the IGBP is the International Council of Scientific Unions, that also organized the IGY. ICSU is an independent scientific organization founded in 1919 whose members represent the principal scientific academies and research councils of 68 countries, and the international unions of the exact and natural sciences, such as the International Union of Bological Sciences, the International Astronomical Union, and the International Union of Geological Sciences. Initial steps to consider an IGBP have already been taken within ICSU through the instigation of Dr. Thomas F. Malone, Treasurer of ICSU, and Dr. Herbert Friedman, both of whom represent our National Academy of Sciences and National Research Council.

The U.S. focal point for an IGBP is the National Research Council of the National Academy of Sciences; the Committee that I represent is directly responsible to the NRC.

QUESTION 3:

It seems that the IGBP may not be ready to commence before other important NASA programs such as Global Habitability are under way.

a. Do you believe such NASA programs or satellite launchings should be delayed to be compatible with IGBP?

ANSWER:

The IGBP would not come into being until about 1990, at which time it would act in part to coordinate and strengthen certain strong disciplinary and interdisciplinary programs already underway. NASA's program in Global Habitability is a good example, as may be parts of the World Climate Program, the World Ocean Circulation Experiment, the International Solar Terrestrial Physics Program, and the International Biological Program. There is no cause to delay the progress of any of these and it would be counterproductive if this were to happen; an eventual IGBP will far stronger and more successful if component programs are already in place when it begins.

QUESTION 4:

What has been the reaction of other countries and international bodies such as the United Nations Environment Program to the IGBP?

ANSWER:

The reaction of scientific leaders of other nations, contacted informally and within ICSU, has been almost entirely positive and I think there is every reason to believe that support for an IGBP will continue to grow as the notion is more clearly defined and more widely known. The IGY was an extremely popular program before, during, and after its short lifetime, with the strong support of both policy makers and eminent scientists in almost all nations. I think we can expect a similar response to a well-defined IGBP.

a. Why is it necessary for IGBP to gain the approval of the International Council of Scientific Unions?

ANSWER:

The basic tenet of an IGBP is that global problems require international cooperation for their solution. The taking of data relevant to the biosphere and atmosphere, for example, requires the participation of the countries who control the land areas involved. An International Geosphere-Biosphere Program is meaningless unless it secures both the support and the willing participation of many nations -- the major scientific powers and the minor ones -- and this means soliciting ideas as well as consent at the earliest planning stages. This seems best and most efficiently done through the existing International Council of Scientific Unions, which brings together not only many nations but the many scientific disciplines that are involved.

b. Do you envision that they (ICSU) can secure the approval of their respective governments for IGBP?

ANSWER:

We can hope that this can be done; it was achieved through the same agency 30 years ago for the IGY. Commitment and support can be neither sought nor expected, however, until the aims of the program are made more specific -- a process that has just now begun. We expect that the member academies and organizations of ICSU will soon endorse the plan in principle, and that as the research goals of an IGBP are better defined further efforts will secure the eventual commitment of national programs and resources. As I noted earlier, the IGBP is not envisioned as an umbrella over all efforts in the earth and biological sciences for a decade; it will focus on specific, agreed-upon problems that seem best solved by multi-disciplinary, coordinated attack. By definition, problems selected will be global ones, common to the well-being of life on Earth. I find it heartening that in the past, cooperative scientific programs of this nature, that cut across political boundaries, have found ready support in the international community. That support will almost surely follow a well-planned U.S. lead. If our own country --- the acknowledged leader in science and particularly science from space --- will demonstrate a strong and early commitment to the program then others will follow.

c. Do you envision that our inability to fully follow through on major cooperative proposals such as ISPM will affect the willingness of other nations to make commitments to IGBP?

ANSWER:

There is no question that the NASA withdrawal from prior commitments to the International Solar Polar Mission in 1981 was done at the cost of U.S. credibility as a leader in space science. We have an opportunity now, however, to recover some of that lost faith through the timely deployment of a proposed series of U.S. spacecraft in the International Solar Terrestrial Program, now proposed for 1989-1992. Were I in Europe's ESA or the Japanese ISAS, I would be watching NASA's moves rather closely just now to gauge the real meaning of

U.S. commitments in space research. These programs have long lead times, and affect the FY 1985 and FY 1986 NASA budgets. The ISTP, involving the coordination of six international spacecraft in a cooperative program to probe the magnetosphere and near-Earth space, fits nicely in time and concept with an IGBP. It may or may not become a coordinated part of an IGBP. But it will be watched as a possible model. It may serve as an example of how a broader, international, space-oriented program can be run.

QUESTION 5:

Some of the major objectives you have articulated such as interdisciplinary and international coordination, can also be greatly promoted by some type of Global Resource Information System.

a. Do you agree?

b. Do you believe that this should be a point of major emphasis within IGBP, perhaps one that could begin now?

ANSWER:

A Global Information System through which cooperating nations would enjoy quick or immediate access to shared data is a necessary part of an IGBP. World computer networks make this possible in ways that were only dreamed of in the IGY of 1957. We can fully expect that techniques of data acquisition, storage, and retrieval will advance faster and farther in the years between now and the projected start of an IGBP and we must be ready to make full use of them. Quick and easy access to spacecraft data will bring Third World countries into equal and full participation in an IGBP, and that we can surely all support.

QUESTION 6:

How can a program such as IGBP avoid international political matters such as acid rain and the banning of fluorocarbons?

ANSWER:

Any new knowledge brings with it the potential of practical impact: tracing the factors leading to acid rain is a good example, as is the fuller understanding of regional and global deforestation and desertification, and the clarification of the phenomenon known as arctic haze. A better understanding of the sources and sinks of carbon dioxide and of the global buildup of methane may eventually bring pressures on someone for monitoring or possible controls. Changes in climate, the state of rivers and oceans and polar ice, and the extent of plant and animal life and of the world's mineral resources are all issues of potential political and economic impact. To know how to respond, and to know *whether* to respond, requires a thorough knowledge of the real problem. The alternative to better understanding is ignorance and that can also dictate political matters through rash or misguided action, or inaction. The goals and methods of an IGBP are those of long range research, aimed at understanding and monitoring the subtle and interrelated changes of our environment. I don't believe that any faction, however narrow in its outlook, would intentionally oppose an increase of facts and understanding in any of the issues noted above.

QUESTION 7:

What are the international political implications for IGBP which you expect to encounter?

ANSWER:

In preliminary discussions with scientists from many countries, and particularly with those from the Soviet Union and the Peoples' Republic of China, we have yet to encounter any hint of political implications or opposition, and both

of these countries, particularly China, have been active participants in the preliminary discussions through ICSU. There are encouraging precedents. The U.S. and U.S.S.R. cooperated closely in the IGY, which, in 1957 through 1959, happened to fall at a season of the Cold War that was probably as wintry as is the political climate today. In the interim the nations of the world have continued to cooperate, I think unselfishly and altruistically, in a continuing series of global scientific programs not unlike the IGBP, through, for example, the World Meteorological Organization and similar bodies in other disciplines. I think most scientists and most national scientific agencies would still agree with Anton Chekhov, that "there is no national science, just as there is no national multiplication table."

At the same time it would be naive to suppose that an intensive militarization of space would not in some ways impede a world scientific program whose greatest promise lies in observations made from that high ground. We could note that the oceans were "militarized" centuries ago, and that has not stopped the continued progress of oceanography. Still, I would personally hope that the potential for good in programs like the IGBP would be recognized by this country and others as above the concerns of international politics, and best of all, as a reason to demand that space be used exclusively for peaceful purposes.

QUESTION 8:

The coordinated measurement programs you call for seem to require some specifically planned satellite platforms to be in operation during the 1990 timeframe.

a. Because of the lead time for building such satellites, we have a reasonably good idea what satellite platforms will be operating then. Are these the optimal ones?

b. Should we be thinking about some different or additional satellite platforms?

ANSWER:

A most difficult part of bringing a program like an IGBP to fruition is the international coordination and long-term planning of needed spacecraft. Some of the reasons the IGBP is proposed for the next decade and not next year are the need for long lead times, the concerns for wise and optimal use of expensive platforms, and the need to protect, rather than preempt, planned or ongoing scientific programs of smaller scale. An IGBP will be directed at specific scientific problems that are agreed upon first nationally and then internationally, and these are not yet formulated. At this time we cannot suggest new NASA emphases; nor do we intend to recommend changes or significant delays in programs that have already been carefully planned and justified. An IGBP will succeed only if it is built on strong, existing programs within the disciplines involved. If the goals of an IGBP are adopted, suggestions for different or additional spacecraft to support it will come through the community of organizations and disciplines that now advise NASA in the long-term planning of U.S. spacecraft.

QUESTION 9:

You have given particular emphasis to the need for Sun-Earth interaction studies.

a. Who should be the lead agency for such studies?

ANSWER:

Different missions for the study of Sun-Earth interactions will require different lead agencies. Some, such as the International Solar Terrestrial

Program, that involves spacecraft of the U.S., ESA, and ISAS, clearly call for a NASA lead, through its program of Earth Science and Applications. Others more properly fall within the province of the National Science Foundation, NOAA, or the Department of Energy.

b. Do modeling efforts suggest specific linkages that would give guidance for a scientifically based measurement program in this area?

Progress made in modelling and other theoretical considerations all point to the need for *in situ* measurements of physical and chemical processes throughout the medium that separates the Sun from the Earth. This includes the magnetosphere and near-Earth space, and the upper and middle atmosphere. The bulk of past attempts at defining the varied impacts of solar variability on the Earth have been made by remote inference, and through the detection of end effects, chiefly in the ionosphere and lower atmosphere. Some solar impulses spend their force, unobserved, in the upper atmosphere; others find their way directly to the stratosphere, or in the case of visible and infrared radiation, to the surface of the Earth. The possible linkages through which upper atmosphere perturbations are propagated downward are known only poorly, and largely through conjecture and theoretical modelling. Spacecraft now make it feasible to trace the course of solar disturbances, step by step, to their ultimate dissipation, and to measure specific responses to known solar impulses. It is in this way that we can hope to learn the limits of their effects, and to understand the linkages through which solar impulses perturb the atmosphere and the Earth. The planned ISTP and UARS missions are capable of making many of these measurements, and both seem to me suited for possible IGBP emphasis. Equally important are spacecraft and instruments dedicated to monitoring the flow of radiation and particles from the Sun, and the continued study of flares and other dynamic changes at the Sun itself, for which the Solar Optical Telescope is intended. An ideal program in Sun-Earth interactions would keep a continuous eye on the Sun while monitoring *in situ* changes in the environment of Earth and throughout the atmosphere.

QUESTION 10:

Global change and biospheric/geospheric influences take place on time scales ranging from tens of years for atmospheric effects to millions of years for many lithospheric processes. In order to avoid the perception that IGBP will simply study everything, it seems necessary to focus on some set of interactions that can be reasonably well defined.

a. What would you include in the earth sciences?

b. What lithospheric processes do you think are important?

c. How can we define the important interfaces between the oceans, atmosphere, and space which are of greatest importance?

ANSWER:

All would agree that an IGBP needs a sharp and defensible focus and that an international, multidisciplinary study of everything on all time scales is ridiculous. I think almost all would agree that an appropriate, general emphasis for an IGBP is on processes of global change, of the sort that so often involve the interaction of the ocean and atmosphere, biosphere and geosphere. Many of the most pressing problems involve climate in some way, and what have come to be known as biogeochemical cycles: the buildup of methane, or carbon dioxide, for example. But the choice of problems for an IGBP, particularly when that choice may commit not only funds but, in the 1990's, a new generation of scientists, must be made carefully and I think conservatively, with the full participation of all who may be involved. The U.S. Committee for the IGBP was formed this year to define a number of specific, initial problems in the earth sciences, including the biosphere, that seem most pressing and best suited to a multidisciplinary approach. Scientific leaders of other nations will be doing the same thing, and from these efforts should emerge a strong and mutually acceptable program. At this time I would not try to anticipate any of the anticipated recommendations, other than to assure you that for our part they will be critically chosen and scientifically sound. Nothing less stands any chance of endorsement and adoption.

Mr. VOLKMER. All right. Thank you very much, Dr. Eddy. From reviewing your statement and listening to you also, it appears fairly certain that we will have an international geosphere/biosphere, or international association, or whatever you want to call it, eventually, and it is several years down the road. Correct?

Dr. EDDY. I think that's inevitable, Mr. Chairman.

Mr. VOLKMER. All right. As a result of that, do you see any demands being made upon NASA for experimentation in space, in the upper atmosphere, let's put it that way?

Dr. EDDY. Right. As I pointed out, I cannot bring to your attention on this day any demands that, say, will greatly affect the fiscal 1985 NASA budget. In time, it is certain to have an effect, but it will be, rather than calling for a new program, in calling for more coordination, more planning involving the international community.

I think a very good example of that is the one that Dr. Coleman mentioned just a few minutes ago, the international solar-terrestrial physics program, which might be a rather good lead case for an IGBP kind of endeavor.

But it does demonstrate the need to plan ahead, to think about our international commitments there. I share with him the concern that there is not enough funds in next year's NASA science and applications budget to allow us to meet that first launch that will make possible that complex of many satellites sponsored by the European Space Agency, by NASA, and by Japan.

I sometimes wonder also if the reason in those agreements that grew out of Williamsburg and later, the reason that the United States was asked to launch their three spacecraft first was kind of a feeling that, "We have to watch these guys. They might not come through, you know. After you, we will launch."

And I think that it's a very good case in point where we must plan ahead, and that's the kind of planning that will be required.

Mr. VOLKMER. Does any of this international geosphere/biosphere proposed program in any way have to do with or grow out of, let us say, the Unispace Conference in Geneva in 1982 and the proposal or commitment, I guess, that we made on the global habitability program?

Dr. EDDY. The IGBP has a lot of overlap with that program that NASA began and, as I understand, presented to the congress you mentioned. It is broader, however, in that the IGBP embraces as well the solar-terrestrial part of the connection. I think it puts more emphasis on studies of the lithosphere as a written record of the past history of the planet.

But they are somewhat overlapping, and as I pointed out, I think in time you will see them woven together into one program. So, yes, I think these earlier NASA emphases will be part of it.

Mr. VOLKMER. What you are describing to me as the international geosphere/biosphere would basically encompass every part of it.

Dr. EDDY. I think that's true if you are speaking of the NASA study of biogeochemical cycles, which would be a strong part of it. But we are talking about a program here that, even though I am testifying for consideration of the NASA budget——

Mr. VOLKMER. Goes beyond that.

Dr. EDDY [continuing]. Goes beyond NASA.

Mr. VOLKMER. Oh, yes.

Dr. EDDY. Yes.

Mr. VOLKMER. It goes well beyond that. I can understand that. But the part that NASA would basically play, that I can see—you correct me if I am wrong—is basically providing those things in space that would provide instrumentation to make determinations.

Dr. EDDY. That is correct.

Mr. VOLKMER. And, of course, we have got to start on the upper atmospheric research satellite, UARS, this year proposed. That will be beneficial toward the tethered satellite that——

Dr. EDDY. Yes.

Mr. VOLKMER. They are working with Italy. That would be beneficial.

Dr. EDDY. It certainly will. And I think that also gives me an opportunity to point out how much I also applaud the inclusion of the UARS step this year in the NASA budget. But it's an example of your initial question, how does the IGBP affect present budgeting or future budgeting. It is certainly not intended or even unintended to be something that is going to co-opt such programs or to delay them in how they come about.

We look upon UARS, we look upon the world oceans climatology experiment, the international solar-terrestrial physics program as in a way steps towards this kind of idealistic union of the sciences and international effort.

Mr. VOLKMER. The scatterometer would have an influence.

Dr. EDDY. The scatterometer thing would have a very big influence, and that is another—thank you for reminding me of it—another very good step in the direction of this kind of science. We applaud that there. But again, I am speaking for myself.

Mr. VOLKMER. May I ask you just yet on a general science thing?

Dr. EDDY. Yes.

Mr. VOLKMER. I did not do well in college on science, but I have always been interested in it.

Do we know as of now—let us get into atmosphere, the CO_2 and methane and that type of thing, which you touched on in your talk—is the density of it basically uniform around the Earth's sphere, or does it vary? In other words, we use a lot more types of fuels, et cetera, fossil fuels than a lot of other places.

Dr. EDDY. Yes.

Mr. VOLKMER. And other places have a lot more forests and trees and things. Does that make a determination in that area, or do the winds move it?

Dr. EDDY. In the case of carbon dioxide, we are dealing with a global gas that the first approximation at least is very well mixed globally. In that sense, it's a good example of a global problem that can be induced by local inputs.

I think the same is generally true of methane. For example, I am personally interested in the reading of the past history of carbon dioxide and the components of carbon dioxide and what they will tell us about climate in the past and even the Sun in the past. There we find that the carbon-14 that is part of carbon dioxide is pretty uniformly distributed in the trees that have grown around the Earth, that one can sample the amount of past carbon-14 in

decades or centuries or even longer past by reading a tree that grows in Missouri as well as one that grows in Lebanon.

So we have a case of a truly global mixing and a reminder of the global nature of many of these problems.

Mr. VOLKMER. Do we therefore find the density—what you are telling me is that around the North and South Poles, where we really do not have any fossil fuel burning and we do not have any trees——

Dr. EDDY. Right.

Mr. VOLKMER [continuing]. But yet we still find it.

Dr. EDDY. Well, one of the most intriguing probes into the carbon dioxide problem is looking into the past, and the carbon dioxide that's found in the ice of the two polar regions. There again, the ice has been one of nature's natural diaries that recorded what's going on on the rest of the Earth. These, of course, are for first approximation, and there will be minor differences over the globe.

But in the case of that gas, we do have it globally distributed. It's locked in the ice in the poles. I personally find it kind of beautiful the way nature keeps diaries for us, almost in spite of ourselves, of what has happened in the past.

Mr. VOLKMER. In other words, would it be so that as the Ice Age then regressed, that we had more CO_2 possibly released?

Dr. EDDY. You say you didn't follow science that well, but I think you must, to ask such a question, because that's a very intriguing insight into the carbon dioxide problem, and it shows its complexity. The predictions now, you know, are that because of the hand of you and me, we are messing up the atmosphere by dumping lots of carbon dioxide there. It is going to have a big effect climatically.

Yet, when we look into the ice that came from Greenland during the time of the last Ice Age, we see a very great drop in the amount of carbon dioxide. And yet, at that time, Cro-Magnon man was putting in very little carbon dioxide into the atmosphere, and yet it seems to have played some kind of role independent of man.

In that sense, it is much like the politically sensitive fluorocarbon issue or ozone. To understand them, we must know what are nature's variations before we can begin pinning the blame too much or making too good a prediction.

Mr. VOLKMER. I have no further questions. Does the gentleman from Texas have any questions?

Mr. HALL. No questions, Mr. Chairman.

Mr. VOLKMER. Well, I look forward to discussing, Dr. Eddy, with you, as I am sure, like you say, it is inevitable we have the international geosphere/biosphere. I am sure that, hopefully, we will have a lot of international cooperation in that and learn more about where we live and the influences not only of man but of the Sun and the winds and everything else on us, so maybe somebody will still be here 100 years from here, or 1,000 years.

Thank you very much for being here today.

Dr. EDDY. Thank you, Mr. Chairman.

Mr. VOLKMER. We will now adjourn.

[Whereupon, at 11:25 a.m., the subcommittee was adjourned.]

1985 NASA AUTHORIZATION

WEDNESDAY, FEBRUARY 22, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 1:02 p.m., in room 2318, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Present: Representatives Volkmer, Brown, Nelson, MacKay, Dymally, Lujan, Chandler, Lowery, Bateman, Walker and Winn.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

This hearing is part of our continuing review of the NASA fiscal year 1985 budget request. Today we will focus on the Office of Space Flight and review NASA's budget request for space transportation programs, including the space shuttle and expendable launch vehicles and upper stages.

We are delighted with the excellent continuing progress that NASA has made in the past year in operating the space shuttle. In the last 12 months, the second orbiter—Challenger—was flown for the first time and the third orbiter—Discovery—was delivered to the Kennedy Space Center. Also, the space shuttle successfully demonstrated its ability to make night launches and landings, remain on orbit for 10-day missions, and land on the hard surface runway at the Kennedy Space Center.

On the other hand, we continue to be concerned that the approved orbiter fleet size may not be adequate to satisfy user needs or the flexibility to respond to lengthy orbiter down times or attrition without a serious impact on numerous payloads on the manifest.

Further, we are concerned by factors that may hamper the ability of the space shuttle to achieve a launch rate of 24 flights per year and continuing failures of some elements of flight hardware.

Finally; in today's hearing we will review NASA's budget request; discuss the need for an extended on-orbit capability of the orbiter; scrutinize some organizational changes that have been suggested by concerned observers; and explore NASA's positions on expendable launch vehicles and upper stages, shuttle marketing efforts, and the shuttle pricing policy.

Our witness today will be Lt. Gen. James A. Abrahamson, Associate Administrator for the Office of Space Flight. I would like to welcome you, General Abrahamson, for once again being here to testify regarding this important part of NASA's activities.

At this time I will recognize the gentleman from New Mexico for an opening statement.

Mr. LUJAN. Thank you, Mr. Chairman.

I am most anxious to hear General Abrahamson. I do have a prepared statement, but I will forego it at the moment so we can get right on to the testimony, but I ask unanimous consent to include my statement in the record.

[The prepared statement of Mr. Lujan follows:]

HONORABLE MANUEL LUJAN, JR.
HEARING ON SPACE TRANSPORTATION SYSTEM
FEBRUARY 22, 1984

THANK YOU, MR. CHAIRMAN. WELCOME GENERAL ABRAHAMSON. IT IS ALWAYS A PLEASURE TO HAVE YOU VISIT WITH US. THE SUBJECT OF SPACE TRANSPORTATION HAS RECEIVED A LOT OF ATTENTION THIS PAST YEAR. THIS HAS BEEN A SPECTACULAR YEAR FOR THE SPACE SHUTTLE PROGRAM. THE ORBITER FLIGHTS HAVE HELPED RECAPTURE THE PUBLIC IMAGINATION ABOUT THE PROSPECTS OF SPACE. THE RECENT ANNOUNCEMENT BY THE PRESIDENT OF THE GOAL TO HAVE A SPACE STATION OPERATING WITHIN A DECADE HAS DEMONSTRATD THAT THERE IS A GROWING NEED FOR SPACE TRANSPORTATION. CLEARLY THE SHUTTLE WILL PLAY A MAJOR ROLE FOR THE DEVELOPMENT OF THE POTENTIAL IN SPACE.

THE PRESIDENT ALSO HAS SHOWN HIS VISION OF THE FUTURE FOR SPACE PROGRAMS BY EMPHASIZING HIS SUPPORT OF DEVELOPING THE COMMERCIAL POSSIBILITIES OF SPACE. HE ESPECIALLY POINTED OUT HIS SUPPORT OF THE COMMERCIALIZATION OF ELV'S. I BELIEVE THAT HOW WE APPROACH THE ISSUES ASSOCIATED WITH SPACE TRANSPORTAION WILL DETERMINE HOW SUCCESSFUL MANKIND IS IN USING ALL THE POSSIBILITIES OF SPACE. I BELIEVE THE RESOLUTION OF THESE ISSUES MAY BE CRUCIAL IN DETERMINING THE FUTURE OF THE U.S., IN TECHNOLOGICAL AND ECONOMIC LEADERSHIP.

WHEN THE AIRPLANE WAS FIRST DEVELOPED, WE DID NOT ABANDON USE

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OF THE AUTOMOBILE, BUT RATHER RECOGNIZED THAT BOTH FORMS OF TRANSPORTATION SERVED AN IMPORTANT ROLE, AND THAT BOTH FORMS OF TRANSPORTATION WOULD BE USEFUL IN DEVELOPING THE U.S. ECONOMY. I BELIEVE WE ARE AT A SIMILAR POINT TODAY WITH THE SPACE TRANSPORTATION SYSTEM. THE SPACE SHUTTLE IS DEFINITELY A UNIQUE CAPABILITY. THERE ARE MANY ACTIVITIES THAT CAN NOT REASONABLY BE DONE IN SPACE WITHOUT THE SHUTTLE, BUT THERE IS ALSO A ROLE FOR COMMERCIAL ELV'S.

THE SHUTTLE SYSTEM HAS MANY DIFFERENT CUSTOMERS: THE DoD, SCIENTISTS AND RESEARCHERS, COMMERCIAL COMMUNICATIONS FIRMS, AND INTERNATIONAL INTERESTS. AS THE SHUTTLE USE GROWS, THERE WILL ALSO DEVELOP A COMPETITION FOR ACCESS TO THE SHUTTLE. I BELIEVE THAT RIGHT NOW WE ALL ARE CONFUSED ABOUT WHAT SHOULD BE THE RELATIVE PRIORITIES OF THE SHUTTLE USE. OF COURSE, EACH OF THESE USER COMMUNITIES CAN PROVIDE GOOD ARGUMENTS ON WHY THEIR ACCESS TO THE SHUTTLE SHOULD BE THE TOP PRIORITY. BUT WE ALSO NEED TO ASK OUR ULTIMATE BOSS -- THE TAXPAYERS. FOR THIS TO BE CLEARER WE ALOS NEED A BETTER UNDERSTANDING OF THE VARIOUS COSTS AND BENEFITS.

WE NEED TO THINK CAREFULLY ABOUT THOSE CONFLICTING PRIORITIES WHEN CONSIDERING THE SHUTTLE PROGRAM. WE ALSO NEED TO CONSIDER THE IMPACT OF FEDERAL POLICIES ON THE DEVELOPING SPACE INDUSTRIES. IT MAY BE POSSIBLE TO OPTIMIZE THE USE OF THE SHUTTLE AND AT THE SAME TIME ENCOURAGE THE DEVELOPMENT OF COMMERCIAL ELV CAPABILITY.

I LOOK FORWARD TO HEARING YOUR TESTIMONY AND DISCUSSING THESE AND OTHER SPACE TRANSPORTATION ISSUES WITH YOU.

THANK YOU, MR. CHAIRMAN.

Mr. VOLKMER. Thank you.

I also recognize that we have today the ranking minority member of the full committee, Mr. Winn from Kansas, with us today.

At this time I will recognize General Abrahamson. Your prepared statement, which you have been so kind as to furnish us, will be made a part of the record at the conclusion of your oral presentation. You may either summarize it or review it in full, however you so desire.

General Abrahamson.

STATEMENT OF LT. GEN. JAMES A. ABRAHAMSON, ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE SCIENCE & APPLICATIONS, NASA; ACCOMPANIED BY JESSE MOORE, DEPUTY ASSOCIATE ADMINISTRATOR AND MACK STEEL, DIRECTOR OF RESOURCES AND INSTITUTIONS

General ABRAHAMSON. Mr. Chairman and distinguished members of the subcommittee, it is always a pleasure to be back here.

I have some supporting witnesses. I would like to introduce Mr. Jess Moore, who is my deputy in the Office of Space Flight; and Mr. Mack Steel, who takes care of all of our budget and financial activities. I have several other of our division directors who are here to try to answer any questions just as quickly as possible rather than going to the record, although sometimes we may have to.

I believe that we are the lucky ones in that we get to represent not only the Headquarters Office of Space Flight, but it is our real privilege to be working on this program and to represent the thousands of NASA men and women and contractor men and women who really make up this very powerful team. We feel that we have made substantial progress.

Rather than read my entire statement, what I would like to do is to just summarize with part of the introduction, present two slides which provide the budget summary, and I will leave room for your questioning.

If I may, then:

As we have recently witnessed from our last exciting mission, the space shuttle continues to prove itself a versatile element of an overall space transportation system. Since our appearance during last year's budget hearings, the outstanding NASA, industrial, and academic mission team has continued to demonstrate the operational capability and the potential of the shuttle.

As I have mentioned to many of you on other occasions, the Space Transportation System has revolutionized space exploration and exploitation and, in my judqment, we should be proud of our accomplishments as we continue to demonstrate scientific and technological firsts through our routine access to space. We are now in a position to further capitalize on our great national asset without increasing our budget request. Our fiscal year 1985 budget request for the Space Transportation System program is $3.166 billion, which is 10 percent less than our fiscal year 1984 budget. This includes $2.8 billion for space flight, control and data communications, and $361 million for research and development.

Before turning to the details of the budget request, I would like to review a few of our major accomplishments during 1983 as well as give you a status report on the programs being conducted in 1984.

During the past fiscal year, as you mentioned, the delivery of the *Challenger* expanded our orbiter mission fleet to two vehicles. The third vehicle, *Discovery*, was delivered to Kennedy Space Center in November and is being prepared for its maiden flight this June. *Atlantis*, our fourth orbiter, is scheduled for delivery toward the end of this year and will begin to meet operational demands in 1985. By the way, those ontime and under-budget deliveries are a very noteworthy point for the program, in my judgment.

Since last year's budget hearings, we have completed five missions. These flights included the deployment of several commercial and foreign communications satellites—for Telesat Canada, Indonesia, and for India. Two communications satellites for Western Union and Indonesia were successfully launched from the shuttle but failed to achieve their proper operational orbit. Additionally, we launched the first of three tracking and data relay satellites, TDRS, and while the deployment of the TDRS was successful, we again suffered a failure of the—this time—inertial upper stage, which delayed the positioning of the satellite into its proper orbit. A superb NASA and contractor engineering team saved the situation by executing a series of maneuvers that included the firing of 1-pound thrusters on the spacecraft to achieve its planned orbit in time to support the spacelab mission. Indeed, it may be that our most reliable upper stage is that little 1-pound thruster in the TDRS.

We achieved great strides in extra-vehicular activity on two separate missions. On the STS–6 flight, two mission specialists took the first spacewalk for the United States since the skylab program. While tethered to the orbiter, the specialists conducted exercises to improve our ability to use tools and perform equipment handling techniques in the cargo bay.

The successful test of astronauts, their spacesuits, and the untethered manned maneuvering unit on the recent 41–B mission demonstrates an additional EVA capability that shows great promise for repairing satellites and extending their lifetime.

The capabilities of the Canadian-built remote manipulator system were also demonstrated in 1983. The RMS has worked effectively on six missions, with a partial failure on our recent flight. During the STS–7 mission, the RMS was flawless as it achieved the first deployment and retrieval of a spacecraft, the West German shuttle pallet satellite, SPAS, from the cargo bay. It was this spacecraft which served as a pallet for several scientific experiments and qave us the first pictures of the orbiter in flight. The ability of the RMS to lift large objects was also successfully demonstrated on the STS–8 mission on tests with the payload flight test article, the heaviest payload it has lifted. During the last mission, the MMU docking test with a rotating target was scrubbed because the RMS wrist yaw joint would not respond to single direct drive commands. This failure will not constrain the upcoming solar maximum repair mission, flight 41–C.

While our flights have been scoring many great engineering accomplishments, the capabilities of the shuttle to provide outstanding scientific benefits have also been illustrated. The greatest example of this was the resounding success of the spacelab mission on STS–9. This joint NASA-European space agency mission, flown last November, was an unqualified success, demonstrating the versatility and broad applicability of this new space research facility.

This historic flight represented the fruition of an international effort of individuals representing a broad spectrum of Government, industry, and the scientific community over a 10-year period. More than 100 investigators from 11 European Nations, Canada, Japan, and the United States provided over 70 experiments in 7 scientific disciplines. Never before has so much scientific data been brought back from a shuttle flight.

All of spacelab's verification objectives were accomplished. For the first time during a flight, principal investigators were able to communicate directly with the crew, monitor real-time data, and give instructions for their experiments through the payload operations control center. Once again, we dramatically demonstrated the flexibility of manned space flight operations by the STS–9 crew's ability to modify experiments, improvise, and even make dramatic equipment repairs.

Additional scientific experimentation was accomplished on STS–7 with NASA's Office of Space and Terrestrial Applications payload, OSTA–2, which remained fixed inside the payload bay to perform materials processing experiments. These four instrument packages, developed by United States and West German scientists, investigated the mixing, melting, and crystallizing of such substances as metal alloys and glass.

The shuttle revolution has also made it possible for us to offer space experimentation opportunities to new classes of investigators through our small self-contained payload program, better known as the getaway specials. Over 400 reservations for these specials have been booked, and during the past year 19 experiments have been carried on shuttle missions. The GAS experiments included investigations by high school and college students, foreign governments, DOD, U.S. firms, and NASA. The investigations have included experiments with plants, seeds, metals research, snow crystals, ants, and soldering, to name a few.

The middeck of the orbiter also offers experimental opportunities for the science community. Since last year's hearings, we have performed middeck experiments on monodisperse latex spheres, studies of lightning associated with thunderstorms, and plant experiments. This is also the location from which most of our high school shuttle student involvement project experiments are conducted.

On the last 5 flights, we have sent up 25 crew members who performed their duties with a level of excellence that has again and again proven the value of having people in the loop to conduct mission activities and to initiate corrective action when necessary.

This brings the number of crew members who have participated in shuttle missions to 37, including 20 astronauts, 15 mission specialists, including the first female and the first 2 blacks, and the first 2 payload specialists, 1 from the United States and our first non-U.S. crew member.

We will continue to expand opportunities for space flight both within and outside the United States. Our roster of 76 crew members will be expanded this year as a result of last year's call for new astronaut candidates. We expect to select approximately twelve new crew members this coming spring. As an aside, those interviews are going on this week down at the Johnson Space Center.

The first payload specialist representing a U.S. company will fly this year when a McDonnell Douglas employee will conduct its continuous flow electrophoresis experiment. Several foreign countries are also currently conducting their own selection procedures for payload specialists to fly on missions carrying their country's spacecraft and experiments.

In addition, a great deal of enthusiasm has recently been generated for a new program we are initiating that will allow private citizens to fly as participants on shuttle missions. Planning to develop this opportunity began in 1983, and it is likely that the first private citizen could fly as early as 1985.

Now, the rest of the prepared testimony goes into the budget, and I would like to just show what I consider to be a very important budget trend both for the shuttle program and for the agency.

[Slide shown.]

Here we have the defined program for fiscal years 1984, 1985, and out through 1989. What you see is—by the way, this does not include new starts. This is the baseline program as presently approved. What you see is a projection which is a confident projection as we go out that our budgets will be coming down dramatically out through fiscal year 1989. Out there we do see a level-off period, although it is hard to be able to project exactly what will happen.

You can also see the importance of reusable operations and reusable funding as that begins to become ever a larger part of the operational budget itself.

Could you put up the next one, please, Alan?

[Slide shown.]

I am sorry, reimbursable, not reusable. [Laughter.]

We have a reusable spacecraft but not very reusable money, unfortunately. [Laughter.]

Here are the details of our budget in 1985 and, for reference, going back to 1984 and 1983. Here you can see our total reduction of about 10 percent, going from the 3.5 in 1984 down to the 3.1 in 1985.

That reduction comes from several things, one, the place where we are in the program. Another—and I have to emphasize what I consider to be the outstanding management at all levels at our centers and with our project directors. We have achieved very important savings that we have then been able to reapply as we go foward to meet the needs of the program.

With that, I would like to save the rest of any comments on that for your questions; but I would like to comment at least with the last paragraph in the written testimony, and that is for our newest step in space, the space station itself.

The STS team is enthusiastic about the President's initiative to go forward with a space station. The space transportation system will, of course, play a vital role in the development and eventual

operation of the station. In the near term, we will use the shuttle's research capabilities to gain experience and insight into designs and systems that are essential elements of any space station concept.

Since the shuttle will be the primary vehicle that will allow us to carry personnel and equipment to build and maintain a station, those of us connected with the space transportation system have a special incentive to insure routine and reliable space transportation both now and for the future. We are proud of our contributions and the space shuttle's role in the revolution in space that is clearly underway.

Your cooperation and support has been a firm foundation for the incredible accomplishments of our space program during NASA's first quarter century. We look forward to our partnership and your inspiration for the next logical step in space exploration and exploitation.

With that, sir, I am ready for any of your questions.

[The prepared statement, plus answers to additional questions asked of General Abrahamson follow:]

Statement of

James A. Abrahamson
Lieutenant General, USAF
Associate Administrator
Office of Space Flight

National Aeronautics and Space Administration

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Distinguished Members of the subcommittee:

As we have recently witnessed from our last exciting mission, the Space Shuttle continues to prove itself a reliable and versatile space transportation system. Since our appearance during last year's budget hearings, the outstanding NASA/industry/academic mission team has continued to demonstrate the operational capability and potential of the Shuttle.

As I have mentioned to many of you on other occasions, the Space Transportation System has revolutionized space exploration and exploitation and, in my judgement, we should be proud of our accomplishments as we continue to demonstrate scientific and technological firsts through our routine access to space. We are now in the position to further capitalize on our great national asset without increasing our budget request. Our FY 1985 budget request for the Space Transportation System Program is $3.166 billion, which is 10% less than our FY 1984 budget. This includes $2.805 billion for Space Flight, Control and Data Communications and $361.4 million for Research and Development.

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(ESA) mission, flown last November, was an unqualified success, demonstrating the versatility and broad applicability of this new space research facility.

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and again proven the value of having people in the loop to conduct mission activities and to initiate corrective action when necessary. This brings the number of crew members who have participated in Shuttle missions to 37, including 20 astronauts, 15 mission specialists (including the first female and the first two blacks), and the first two payload specialists, one from the United States and our first non U.S. crew member.

We will continue to expand opportunities for spaceflight both within and outside the United States. Our roster of 76 crew members will be expanded this year as a result of last year's call for new astronaut candidates. We expect to select approximately twelve new crew members this coming spring.

The first payload specialist representing a U.S. company will fly this year when a McDonnell Douglas employee will conduct its Continuous Flow Electrophoresis Experiment. Several foreign countries are also currently conducting their own selection procedures for payload specialists to fly on missions carrying their country's spacecraft and experiments.

In addition, a great deal of enthusiasm has recently been generated for a new program we are initiating that will allow private citizens to fly as participants on Shuttle missions. Planning to develop this opportunity began in 1983 and it is likely that the first private citizen could fly as early as 1985.

Our ability to accomplish all that we have on these missions is due to great progress with the following elements of the Space Transportation System and the industry/government/academic team. I've already mentioned that we are making sound progress in completing the Orbiter fleet. The Orbiter spares program has received a great deal of emphasis. The content of the structural spares program has been finalized, and procurement and fabrication of these major elements is underway. This activity will continue through 1987, maintaining in part the production base. This program will provide a set of major structural elements that can be used as spares to the orbiter fleet, providing additional assurance in the event of damage to an orbiter. By having these structural spares, we will also reduce the lead time to build an additional orbiter if one were required. The Orbiter logistics program also has progressed. This program will provide the initial lay-in of spares, flight rate spares and a repair capability. Orders are being placed, and fabrication is underway for these procurements. Initial lay-in will be completed in 1986. Flight rate spares procurement and repairs will be an ongoing activity to maintain the fleet.

To accommodate our expanding fleet and operational capabilities the second set of high bays in the Vehicle Assembly

Building (VAB), the software production facility, and the second control room were activated at KSC to enable parallel processing of two sets of hardware through Orbiter-External Tank mate. We also inaugarated use of our second Mobile Launch Platform which enables much faster pad turnaround times.

Major progress has been made to obtain the most efficient and cost-effective Shuttle processing services by consolidating fourteen separate contracts under the Base Operations Contract (BOC) and eleven contracts under the Shuttle Processing Contract (SPC). As we entered this new era of contracting, we placed great emphasis on the reduction of multiple contractor interfaces and on the reduction of the numerous approval requirements, detailed instructions, and serial involvement in processing by KSC. These changes give the contractors more direct responsibility and incentive, and holds them more accountable for their performance. The BOC, implemented on January 1, 1983, has already demonstrated the benefits in increased productivity and reduced costs. The BOC was awarded to EG&G to establish single on-site, consolidated institutional support to all functions at the Kennedy Space Center. The SPC was awarded in September 1983 to an industrial consortium led by the Lockheed Corporation. This has served to consolidate launch and landing activities as well as operations of related ground systems at both KSC and the Vandenberg Air Force Base launch site. The transition phase for this contract is essentially complete at KSC with the SPC assuming the full responsibility for the turnaround processing of the 41-C mission--expected to be the shortest turnaround to date.

At Johnson Space Center (JSC), changing our current multicontractor operation to a single STS Operations Contract is being planned to consolidate JSC STS Operations and achieve operational economies. Preparations for flight, that were baselined in 1983 to begin with the issuance of the Payload Integration Plan (PIP) 35 months prior to launch, have now been shortened to begin 25 months prior to launch, and are planned to be further shortened to begin approximately 16 months prior to launch.

As you are well aware, the plan to achieve 24 flights per year, with about 20 at KSC, is highly dependent on our ability to turnaround flight hardware in an expeditious manner. Our initial experience between STS-1 and STS-2 was a turnaround of 187 working days. Continuous planning and optimization of activities, hardware, support equipment and facilities have resulted in reducing this turnaround time on the same vehicle to 55 working days between STS-7 and STS-8. This is projected to continue to improve with a goal of 35 work days turnaround in early 1985.

In the Solid Rocket Booster (SRB) program, FY 1983 saw the delivery of 10 rockets (5 flight sets). We developed and flew a new lightweight case on STS-6, and flew the first high performance motor on STS-8. Throughout the year we continued to expand the existing refurbishment and assembly facilities at KSC, working toward a capability of 16 per year in 1984. A Request for Proposal for recompetition of assembly and refurbishment of the solid rocket frustrum and aft skirt assembly was released in November, with a source selection targeted for later this year. Also during the year we continued with the development program for a filament wound case for the SRB. Through this effort we hope to realize a payload weight capability increase around 4,600 pounds over the metal case.

The External Tank (ET) Program had an exceptionally productive year in 1983. Continued emphasis on producibility and production readiness resulted in a realization of savings in the reduction of ablator on the tank and the first production use of plasma arc welding. The program also saw the delivery of four flight units with the successful first flight of a lightweight tank on STS-6. From a contractual standpoint, several milestones were accomplished to include an incentive contract signed with Martin Marietta Aerospace for the production of tanks through ET-39, and a value engineering clause was added to this production contract.

The Space Shuttle Main Engine (SSME) continued its record of excellent flight performance with the five Shuttle flights completed in CY 1983 and further affirmed its reusability. These flights were completed with no SSME anomalies that impacted flight performance, although STS-6 was substantially delayed due to engine leaks on the ground. This problem was exascerbated by a lack of spare engines, but that has improved as well as our test procedures to assure that leaks are discovered in a timely way. In addition to the continued SSME flight record, the SSME was certified for operations at the full power level (FPL). The total test experience at the 109% FPL includes some 170 tests for approximately 40,000 seconds of operation. The SSME is now certified for those missions requiring FPL thrust. Also during the past year 36 major components were manufactured including four complete SSME's.

While the above achievements are noteworthy, several problems, with serious implications for future operations costs, were encountered during the FPL certification activities. First, while the FPL testing demonstrated that the SSME can now be used to support those missions requiring higher thrust, it still requires extensive and frequent maintenance on the high pressure turbopumps. Secondly, spare engines and pumps (the latter in part as a result of the frequent maintenance) are in short

supply. The lack of spares could have a severe impact on flight operations. The delay to STS-6 that I described is an example.

Design modifications are underway to improve the life, increase the reliability, and reduce the maintenance for several components with the initial emphasis on the high pressure turbopumps. The solutions being pursued consist not only of modifications to the pumps themselves, but also of design improvements for several areas of the turbopumps and a significant redesign of the powerhead and main combustion chamber. These redesigns will reduce the work load on the pumps and lower the temperature and pressure environments, resulting in longer life for many engine components. We are also introducing a strong productivity improvement program, with better procedures, inspection, upgraded tooling and a national initiative in automatic welding of exotic metals.

A key element of the pump/powerhead effort will be the introduction of competition into this phase of the improvement program. The goals of this competition are to ensure that the Agency takes maximum advantage of all available talent and brings a fresh viewpoint to the problems. It should be noted that there is no reason to believe that the current contractor's approach will not be successful, but the turbopump represents difficult problems that have been with us in one form or another for some time now. Thus it is our judgement that parallel approaches to these problems represents a wise investment and will result in significant long term reductions in operating costs.

After careful examination of the overall engine logistics costs, it is clear that the most cost-effective approach is to invest in SSME improvements, as I've mentioned, while adding additional engines as replacement components. Our goal is to both increase engine durability and ensure timely mission support.

In the Upper Stages Program, in 1983 NASA negotiated firm contracts with General Dynamics, Honeywell, Pratt & Whitney, and Teledyne for design and development of the Centaur G and Centaur G Prime, liquid fueled, high energy upper stages as well as procurement of Centaur vehicles for the Galileo and the International Solar Polar missions to take place in 1986. NASA signed an agreement with the Air Force for design and development of a common Centaur stage along with procurement of two stages for the Air Force. During this last year, we completed the Centaur G Prime test vehicles preliminary and critical design reviews along with the flight vehicle critical design review.

As you will recall, the first Inertial Upper Stage (IUS) was successfully launched in October 1982 on a Titan 34-D booster.

The first IUS/STS launch in April 1983, carrying the TDRS-A spacecraft, was marked by several anomalies which are being resolved by joint NASA/AF action. Early in the investigation of the IUS-1 anomalies, it was determined that the techroll seal in the second stage nozzle collapsed and prevented the nozzle from vectoring properly. The anomaly investigation should be completed in 1984 along with the required design changes in the remaining flight vehicles to support the TDRS missions planned for launch by the IUS. Our current scheduling is to have an IUS ready to launch in the late 1984 time frame.

Government-sponsored upper stage activities are being supplemented by the commercial development and operations of other upper stages. One of these, McDonnell Douglas Payload Assist Module-D (PAM-D) successfully launched a total of 16 satellites, 11 on ELV's and 5 on the STS. Of these, 9 were in 1983 (3 for STS and 6 for ELV's) without significant anomalies. However, the Challenger flight, STS-41B, launched on February 3, 1984 carried two reimbursable communication satellite missions which did experience major failures of the PAM. These missions were successfully deployed from the Orbiter bay, but the spacecraft did not achieve proper orbit. The propulsion system for both spacecraft failed to burn for the necessary duration. An investigation team, consisting of McDonnell Douglas contractor personnel who built the PAM-D, the Morton Thiokol Company who built the propulsion system, the spacecraft manufacturer Hughes Aircraft, with NASA and DOD serving in an advisory capacity, is working on the problem. I believe these and other recent failures of solid rocket motors indicates a problem for all launch systems, and we plan a fundamental re-examination of this area of technology. A more powerful version of the PAM-D, called PAM-D II, is now in development at McDonnell Douglas.

The commercial development of a larger capability Transfer Orbit Stage (TOS) was also initiated in 1983. A three axis stabilized perigee stage, TOS is being developed by the Orbital Sciences Corporation (OSC). During 1983 a joint NASA/OSC agreement for commercial development of TOS was negotiated and Martin Marietta Corporation was selecied by OSC as the systems contractor.

The development of the Tethered Satellite System (TSS) is underway with NASA and the National Research Council of Italy having reached agreement on a Memorandum of Understanding for this unique STS facility. The Italians will begin the satellite development effort this spring, while NASA development of the Shuttle deployment mechanism and the tether is already underway. The first flight of this system is planned for late 1987.

In addition to our Space Shuttle missions, the Office of Space Flight also completed 11 highly successful expendable launch vehicle missions in 1983: 8 Deltas, 1 Atlas-F, 1 Atlas Centaur, and 1 Scout launch.

With this background of 1983 highlights, let me spend a few moments on what you can look forward to in 1984.

Columbia, Challenger, and Discovery will be called upon to perform seven to eight missions this fiscal year. Based on the successful demonstration of the Manned Maneuvering Unit on flight 41-B, our next flight will be the first in-orbit repair of an operating satellite - the Solar Maximum Repair Mission. This will be a dramatic mission with astronauts using the MMU as well as the Canadian arm (RMS). Also on that mission we will deploy the Long Duration Exposure Facility (LDEF), a scientific experiment carrier that will remain in orbit for retrieval on a later Shuttle mission.

In the remainder of FY 1984, we plan to deploy six more communication satellites for U.S. and foreign concerns; deploy and recover SPARX-1, a commercial free flyer; and conduct the first dedicated mission for the Department of Defense.

Scientists can look forward to another productive year: Earth imaging data will be obtained during the OSTA-3 mission; technology data from the OAST-1 mission; the deployment of NASA's Earth Radiation Budget science payload; and numerous Getaway Specials and Shuttle Student Involvement Project experiments will also be flown. We expect 21 crew members to participate in these missions.

FY 1985 Budget Request

The total budget authority requested for the Space Transportation Systems Program for FY 1985 is $3.166 billion. Within this request, an amount of $2.8046 billion is requested in the appropriation titled Space Flight, Control and Data Communications. Activities covered here include Shuttle Production and Operational Capability and Shuttle Operations. $361.4 million is requested in the Research and Development appropriation for Space Transportation Capability Development which provides for Upper Stages, Engineering and Technical Base, Spacelab, Payload Operations and Support Equipment, Advanced Programs, and the Tethered Satellite System.

Shuttle Production and Operational Capability

The objectives of this program are to provide for: the completion of the national fleet of Shuttle orbiters; the

production and capability development of the propulsion systems; the mission preparation, mission control, and launch site capabilities; and, the potential changes and upgrading of the Space Transportation System. To support these objectives we are requesting $1.4656 billion in FY 1985. This represents a $183.7 million reduction from the current FY 1984 estimate.

Orbiter

To continue successful Orbiter production activities in FY 1985 we are requesting $606.8 million. This funding provides for the completion of the final stages of manufacturing on Atlantis, leading to its delivery this December. Another major effort will be to complete several modifications to Columbia, bringing it to its operational configuration as well as meeting vehicle loads requirements.

We will continue to provide for procurement of major structural components as spares for the fleet. These structural components will include elements such as wings, vertical stabilizer, crew module, payload bay doors, and aft thrust structure. These elements will be assembled into varying stages of completion to be used as structural spares for the current fleet.

FY 1985 funding will also be used for performance augmentation activities to conduct orbiter loads analysis in support of the SRM filament wound case development program, and for modification of Challenger and Atlantis to accomodate the Centaur Upper Stage.

In FY 1985, systems integration activities will be concentrated on flight program support and on engineering analysis and integration effort for vehicle capability changes, as important Space Shuttle improvements are brought into the program.

Logistics support to the Space Shuttle requires the lay-in of Orbiter initial spares and rate spares to meet the 24 per year flight rate and for ground support equipment needed for replacement of Shuttle components and ground processing operations as the fleet size and flight rate increase. The funding for Orbiter spares covers the cost of spares, ground support equipment spares, and the associated logistics support.

Launch and Mission Support

The budget request calls for $234.8 million for Launch and Mission Support. Other major activities will include the activation of launch pad B, leading to its planned operational

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readiness in January 1986; activation of the third Mobile Launch Platform leading to operational readiness in September 1986; and facility modifications to provide the capability to service the Centaur upper stage for the initial Centaur flights. This is a tight, but doable schedule to support the Galileo and ISPM missions. Modifications to improve the capability of the Spacecraft Assembly and Encapsulation Facility (SAFE-2) by December 1984 and to construct and activate a cargo hazardous servicing facility by October 1985 will be funded from the Construction of Facilities appropriation.

The modification of a third Gulfstream II for use as a Shuttle Training Aircraft, and the expansion of communication, data handling and training capabilities will also be completed in FY 1985. The Mission Control Center upgrades at JSC will be substantially complete in FY 1985 with completion of the Vandenberg interface as well as major progress toward three-vehicle operations capability for supporting higher flight rates.

We will also pursue the development of improvements to the Extravehicular Maneuvering Unit (EMU), to permit quick-response systems for satellite servicing; the requirements foreseen for the Space Station's extravehicular activities are being taken into account to ensure there is a well-integrated approach to meeting future needs of both Shuttle and Space Station operations.

Propulsion Systems

In FY 1985, $599 million is requested for Propulsion Systems. Funding for the main engine provides for those activities necessary to support the orbiter production, flight schedules, and ground testing. Production flows have been adjusted to allow the addition of four new engines. Other ongoing activities will include: flight spares lay-in, and anomaly resolution testing; and continued certification and development testing.

In the Solid Rocket Booster program, we will continue to improve the thrust vector control system and other program elements to minimize damage occuring at SRB water impact and to improve turnaround time on reusable hardware. In the SRM filament wound case development activity, funding in FY 1985 provides for reusability/refurbishment studies and final fabrication activities leading tor delivery of the first flight set.

Through the producibility and production readiness efforts in our External Tank program, enhancements of manufacturing processes to achieve cost reductions will continue.

Procurement of the additional tooling for the SRB and ET programs will proceed as we build up our capability to support the higher flight rates.

Changes and Systems Upgrading

Management, technical flight experiences, and cost reviews of the Space Shuttle program have stressed the need for providing an adequate allowance for changes and modifications which are required in a large, complex, and technically demanding space system. We are requesting funding of $25 million in this area to provide the capability to undertake those changes and upgrading of flight and ground systems needed in the Space Shuttle program. Improvements to system safety, reliability, performance and cost effectiveness are the key objectives.

SHUTTLE OPERATIONS

Shuttle Operations direct appropriated funds are combined with reimbursements received from other U.S. government, commercial, and international customers to support the procurement of flight hardware for launch and flight operation requirements. For FY 1985, $1.339 billion is requested in direct appropriations. The Shuttle operations budget request includes funds in three principal areas: flight operations, flight hardware, and launch and landing operations.

Flight Operations

The Flight Operations request of $316 million provides for the maintenance and operation of the on-board avionics software, mission control systems, as well as astronaut training and flight proficiency aircraft and simulators. It also includes sustaining engineering required to integrate all flight elements and to assure systems safety. The amount required over the core engineering and technical base for the operations and maintenance of the Shuttle Avionics Integration Laboratory (SAIL) is provided to test and verify operations software and hardware modifications. Flight operations also includes Getaway Special support managed by the Goddard Space Flight Center and the payload integration activities at JSC. At the Johnson Space Center, support is included for flight crew mission requirements and safety certification, operations and maintenance support, printing, equipment rentals, and materials for base operations activities.

Flight Hardware

$758 million is being requested for Flight Hardware in FY 1985. Orbiter flight spares and crew equipment spares are based on calculations involving flight rates, maintenance schedules, operational hours, turnaround times, and procurement lead times for spares. Main engine hardware provides for manufacturing and delivery of overhauled engines and engine component spares.

A major portion of this request provides for the delivery of 12 External Tanks and 13 Solid Rocket Booster flight sets in FY 1985 and for the 27 tanks, 17 booster sets that are in the production flow for delivery in subsequent years.

Launch and Landing Operations

Launch and Landing Operations funding of $265 million in FY 1985 provides for manpower to process and integrate STS elements (SRB, ET, Orbiter, payloads) prior to launch , to retrieve the SRB's for refurbishment, and for orbiter landing and return for future flights. Funding also supports sustaining engineering, logistics, launch processing systems, and facility and equipment maintenance. Included in this budget estimate are the projected savings due to the consolidated Base Operations Contract and Shuttle Processing Contracts at KSC.

Expendable Launch Vehicles

The Delta launch vehicle has been the most widely used rocket in NASA's expendable family. Since its first use in 1960, this vehicle has been used in 173 launches with a success record of 92%. No NASA funds are being requested for the Delta in FY 1985 since the last NASA mission scheduled for launch by this system is planned for August 1984. I will discuss commercial plans for Delta launches later in this testimony.

RESEARCH AND DEVELOPMENT

Upper Stages

In FY 1985, $92.4 million is requested for Upper Stage development and procurement. These funds are required to complete the qualification testing on the Centaur G-Prime Structural Test Vehicle and to complete the NASA share of funding for development activities associated with the Centaur G and G-Prime. Funds are also required to support development activities at KSC in preparation for Shuttle/Centaur launches of Galileo and the ISPM in May 1986, and to initiate production of two Centaur G vehicles to support the Venus Radar Mapping mission and the

TDRS-E mission. Funds are also required to complete the procurement of NASA's one remaining Inertial Upper Stage and to support the standby launch capability for TDRS-D. Monitoring of the Payload Assist Modules and the Transfer Orbit Stage will also continue.

Engineering and Technical Base

Requested funding of $105.7 million in FY 1985 for the Engineering and Technical Base provides for a continuation of the FY 1984 level of core support for institutional research and development facilities at the Johnson Space Center, Kennedy Space Center, Marshall Space Flight Center, and the National Space Technology Laboratory. Most of these facilities are operated and maintained by support contractors as over 75% of the Office of Space Flight Civil Service work force are scientists and engineers and professional administrative personnel.

The increase in budget authority over the last fiscal year reflects the effects of inflation and purchase of a class VI computer, an increase in computational capabilities at MSFC for engineering and science projects. The ETB core capability provides for a five-day, one-shift operation at designated OSF installations. Operations support funding provides for the maintenance of technical facilities and equipment, chemical cleaning, engineering design, technical documentation and analysis, telecommunications, photographic support, and logistics support. The budget estimate for launch systems support is required to continue investigations of the research and development technologies available to enhance launch site hardware, ground processing, and support systems.

Spacelab

The FY 1985 funding of $69.3 million will complete the verification of the Spacelab hardware and provide for the flights of operational missions. Funding is required to check out system components before flight, mission planning and training to support the first operational Spacelab flight (SL-3), now scheduled for this November. The second verification flight (SL-2), scheduled for March 1985, will require funding for physical integration, element checkout, training support as well as post-flight analysis.

FY 1985 funding will also be required for the reflight of certain SL-1 instruments on the Environmental Observation Mission (EOM-1). Funding will be applied to processing the first and second flights of the Materials Science Laboratory (MSL). The integration of SL-4, a life science mission, and ASTRO-1, a general ultraviolet astronomy mission which will include

observations of Halley's comet will also be in progress. Analytical integration, configuration management and software development for future flights will be conducted through this budget request.

Procurement of spares for both NASA-developed and ESA-developed hardware will continue in FY 1985. Funds are required to continue the expansion of the Software Development Facility to accommodate the Instrument Pointing System (IPS) software requirements necessary to support the planned flight rate. Production of the second Spacelab unit, under contract with ESA, will continue with the last major components scheduled to be delivered by the end of FY 1985. Funding is required for the initial lay-in and replenishment of spares for the ESA-delivered hardware, and for continuing the establishment and operation of depot maintenance for U.S. provided and European-supplied hardware. The sustaining engineering for all hardware and software beyond ESA's commitment will also require funding in FY 1985.

Payload Operations and Support Equipment

The payload operations support equipment program request of $44.9 million provides for payload services which are required beyond the basic standard Shuttle services. Payload operations provides unique hardware, analysis, and STS launch site services. Payload operations funding in FY 1985 is required to furnish continued payload services for currently scheduled NASA launches. Payloads to receive support include the Galileo, Venus Radar Mapping, ISPM, TDRS, Space Telescope, and Spacelabs 2 and 3. The funding will also support operations and maintenance of the Payload Operations Control Center (POCC) located at JSC to support Spacelab missions, and provide additional Multi-Mission Payload Support Equipment (MMPSE). This equipment is required to integrate, check-out, transport, and provide Orbiter interface to an increasing number and variety of payloads and to provide operational economics through standardization and flexibility.

We will conduct a few inexpensive, but vital, flight experiments to demonstrate new shuttle capabilities aimed at developing customer confidence in connection with satellite services and orbital operations with large structures, such as the Experimental Assembly of Structures in Extravehicular Activity (EASE) and the Assembly Concept for Construction of Erectable Space Structures (ACCESS).

Advanced Programs

Our requested Advanced Programs budget for FY 1985 is $14.5 million. Our major emphasis will be placed on satellite

services, tethers and platforms, advanced transportation systems, crew systems, and proving generic new space systems capabilities.

Detailed definition of Shuttle Derived Launch Vehicles will be initiated to define a potential evolutionary capability for Earth-to-orbit payloads which may capitalize on the STS facilities and productive capability. We will complete concept definition (Phase A) studies, begun in FY 1984, for a potential reusable space-based Orbital Transfer Vehicle to be defined in conjunction with the Space Station definition of accommodation required for its refueling and refurbishment. Phase B systems definition of a potential Orbital Maneuvering Vehicle (OMV) will be completed in FY 1985.

Tethered Satellite System

As I mentioned earlier, the development of a Tethered Satellite System, in cooperation with the Italian government, will provide a new facility for conducting space experiments at distances up to 100 kilometers from the orbiter. The FY 1985 funding of $18.2 million will continue the hardware design and development through the Preliminary Design Review and the Critical Design Review early in FY 1986 with an engineering verification flight in December 1987.

EXPENDABLE LAUNCH VEHICLES

The administration's National Space Policy established basic goals for U.S. Space activities. The first priority of NASA is to make the system fully operational and cost effective in providing routine access to space. It directs that the Space Shuttle be a major factor in the future evolution of U.S. space programs and that it will foster further cooperative roles between the national security and civil programs to insure efficient and effective use of national resources. It specifies that the STS is the primary launch system for both U.S. national security and civil government missions, although it recognized that unique national security conditions may dictate developing special purpose launch capabilities. As a result of this policy, NASA has proceeded to phase out its current Expendable Launch Vehicle systems and as reflected in our FY 1985 budget, no appropriated funds are being requested by NASA for continuation of these vehicle systems. NASA is continuing to respond to users needs in fulfilling our commitments to launch ELV's on a reimbursable basis. In addition, NASA is proceeding to implement National Policy to commercialize Expendable Launch Vehicles as outlined in President Reagan's Policy NSDD-94 dated May 16, 1983. Only two of NASA's Expendable Launch Vehicles are being considered for commercial operations at this time, the Delta and

the Atlas Centaur. Proposals for commercialization of these vehicles have been received and reviewed. Negotiations have been initiated with a goal of establishing commercial operations as early as the beginning of FY 1985.

The current and planned activities that I have reviewed this morning demonstrate that the Shuttle is ready for heavy operational use. At the same time, we see evidence that the commercial sector is viewing the environment of space as a fertile source for experimentation and profit. For the first time in our history, NASA is being challenged by other launch services. To meet this challenge, we are developing a plan to secure launch agreements with free world commercial payload customers.

As the Shuttle increases its service to other customers, reimbursements are projected to increase substantially from $264 million in 1984 to $676 million in FY 1985. These increases, along with the anticipated improvement in Shuttle operations costs, allow us to maintain approximately level funding through FY 1985 while the flight rate is projected to increase from 4 to 11 during the same period. In addition to supporting the flight requirements of the Department of Defense, we fully expect to capture a large share of the foreign and commercial market. Our reimbursement projections are consistent with that expectation.

THE FUTURE

We in the Office of Space Flight are confident that we will continue to improve the efficiency and reliability of the Space Transportation System. We are aware of the challenges that lie ahead and believe we have the team in place to complete the transition to a fully operational system.

The STS team is enthusiastic about the President's initiative to go forward with a Space Station. The Space Transportation System will, of course, play a vital role in the development and eventual operation of the Station. In the near term we will use the Shuttle's research capabilities to gain experience and insight into designs and systems that are essential elements of any Space Station concept. Since the Shuttle will be the primary vehicle that will allow us to carry personnel and equipment to build and maintain a Station, those of us connected with the Space Transportation System have a special incentive to insure routine and reliable space transportation, both now and for the future. We are proud of our contributions and the space Shuttle's role in the revolution in space that is clearly underway. Your cooperation and support has been a firm foundation for the incredible accomplishments of our space program during NASA's first quarter century. We look forward to our partnership and your inspiration for our next logical step in space exploration and exploitation.

SPACE TRANSPORTATION SYSTEMS PROGRAM

FISCAL YEAR 1985 ESTIMATES

BUDGET SUMMARY

SUMMARY OF RESOURCES REQUIREMENTS
(MILLIONS OF DOLLARS)

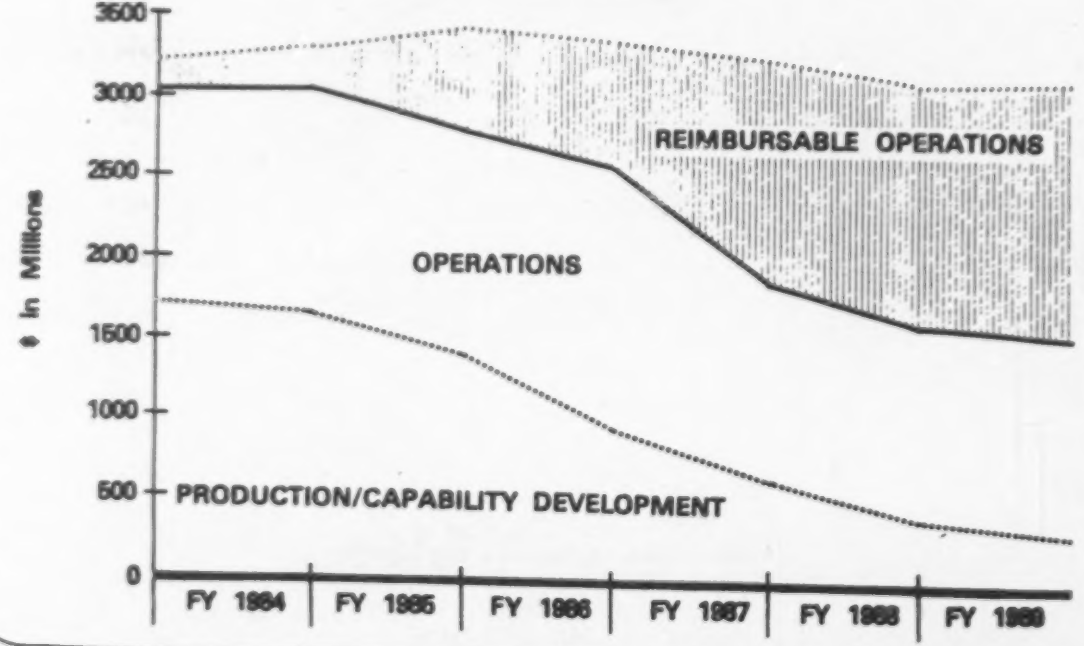
	1983 ACTUAL	1984 CURRENT ESTIMATE	1985 BUDGET ESTIMATE
SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS	3,147.5	3,101.3	2,804.6
SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY	1,725.8	1,649.3	1,465.6
SPACE TRANSPORTATION OPERATIONS	1,421.7	1,452.0	1,339.0
SHUTTLE OPERATIONS	(1,338.7)	(1,402.0)	(1,339.0)
EXPENDABLE LAUNCH VEHICLE	(83.0)	(50.0)	(-)
SPACE TRANSPORTATION CAPABILITY DEVELOPMENT PROGRAM	415.5	431.7	361.4
SPACELAB	121.2	112.5	69.3
UPPER STAGES	167.0	143.2	92.4
ENGINEERING AND TECHNICAL BASE	70.3	93.1	105.7
PAYLOAD OPERATIONS AND SUPPORT EQUIPMENT	44.4	59.6	61.3
ADVANCED PROGRAMS	12.6	20.0	14.5
TETHERED SATELLITE SYSTEM	-	3.3	18.2
TOTAL SPACE TRANSPORTATION SYSTEMS	3,563.0	3,533.0	3,166.0

NATIONAL SPACE TRANSPORTATION SYSTEMS

OFFICE OF SPACE FLIGHT

NASA HEADQUARTERS

SPACE SHUTTLE PROGRAM
FY 1985 BUDGET PLANNING



RESPONSE TO WRITTEN QUESTIONS SUBMITTED AT THE HEARING BEFORE THE HOUSE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS ON FEBRUARY 22, 1984 TO GENERAL ABRAHAMSON.

QUESTION M-1:

Looking into your crystal ball, how many more orbiters do you think NASA will ask to build in the next 10 years?

ANSWER M-1:

Our analyses to date have concentrated on the requirements for additional orbiters through the end of this decade and have shown that the currently approved four orbiters will provide adequate support through that time frame. Beyond that, it is difficult to make a valid projection. Flight experience which is now very limited will also aid in projections of future needs.

QUESTION M-2:

Do you believe we will need a fifth orbiter? When in the future do you anticipate a budget request for a fifth orbiter?

ANSWER M-2:

NASA has continued to study the need for additional Space Shuttle orbiters. These examinations have focused upon impacts of the loss or extended downtime of one of the currently authorized four orbiter fleet and on the likelihood of future traffic growth beyond current capability. These studies have indicated that the current fleet will be sufficient for the remainder of this decade. However, concern was expressed on the need for assurance to accommodate unscheduled maintenance or accidents causing extensive damage or loss of an orbiter.

For this reason, an orbiter structural spares program was initiated in FY 1984. This program provides additional assurance in maintaining shuttle operations and also protects orbiter production capability. This program along with the operational spares program, in our judgment, represents the optimal approach to retention of the planned orbiter fleet and the option to proceed with full production of an additional orbiter at a later date. This issue will continue to be reviewed.

QUESTION M-3:

Though there will be four orbiters in the fleet in 1986, is it not true that NASA has had to turn away at least one paying customer in 1987 or 1988 because his payload could not be accommodated on the manifest?

ANSWER M-3:

NASA has not "had to turn away" any paying customer in 1987 or 1988. We have consistently assured all potential customers that NASA could ultimately accommodate their launch needs on the Shuttle within a month or so of their requested launch date. The appearance of a nearly full manifest is misleading since numerous payloads on the manifest, for various reasons, are not supported by firm launch plans. In addition to assuring potential

customers that we can launch them (so long as we don't commit beyond Shuttle flight rate capacity), we are taking steps to improve the manifest process; so that it reflects the capacity of the Shuttle after adjusting for payloads that do not have firm schedules, etc.

QUESTION M-4:

What would be the impact on the manifest of an 18-month down time by one orbiter in the late 1980s? (Note: Rockwell calculates that the minimum effect would be the loss of 15 payloads (on 8 flights) and the delay of 28 others.)

ANSWER M-4:

Current planning assumes six day, two to three-shift operations at the Kennedy Space Center to support a rate of about seven (7) flights per year per Orbiter.

An eighteen month outage of one Orbiter, therefore, equates to the loss of about ten (10) flights. Pressing the ground operations to seven-days, three-shifts increases the Orbiter usage to about eight (8) flights per year. If more efficient use of the VAFB Orbiter can be achieved, a flight rate of about 24 flights per year could possibly be supported (eight per year per Orbiter for three Orbiters). This would allow us to minimize the impact on payloads to delays ranging from zero to six months.

QUESTION M-5:

We all understand that every transportation mode (rail, truck, ship, and aircraft) experiences attrition over time. Though we hope that the STS never incurs an accident that results in the loss of an orbiter, does it seem reasonable to you to base the long term operation of something as critically important as this country's national space launch capability on the assumption that attrition will never occur?

Is this not reason enough to justify the purchase of a fifth orbiter?

ANSWER M-5:

It is not reasonable to assume that some sort of accident to an orbiter will never occur. Consistent with the President's policy, the orbiter structural spares program initiated in FY 1984 and the operational spares procurement program give added assurance to operation of a four orbiter fleet in a robust manner. Additionally, these programs generally protect orbiter production capability through FY 1986 and maintain the option of adding another orbiter.

QUESTION M-6:

How much of the orbiter production base will be lost by delaying the decision to buy the fifth orbiter for another year?

How much will a one year delay in the decision to buy the fifth orbiter increase the production cost of that vehicle?

Given these facts and NASA's past strong arguments for the need for a fifth

orbiter, wouldn't it be more reasonable to begin production in 1985 rather than delaying it for another year?

ANSWER M-6:

The balance of funding between the in-house effort and subcontractors in the FY 1984 through FY 1986 timeframe retains many essential elements of the Orbiter build capability. However, the Downey/Palmdale assembly workforce will be phasing down with the delivery of Atlantis, scheduled for December 1984, and we will experience some loss of production capability in the final assembly area. Operational and structural spares provisionings have been made to minimize the loss of capability with subcontractors.

Our current assessment shows a one year delay from now in buying a fifth orbiter would result in an additional cost of approximately $200 million.

NASA has assessed the need for a fifth orbiter for the late 1980's and the requirements for one have not been substantiated. It is true, a year's delay in building the fifth orbiter will result in some additional cost estimated at approximately 10 percent. However, we believe the cost associated with gapping has been minimized through the provisioning strategies we are following for structural and operational spares. Additionally, it is our position that, in the long run, demonstrating a firm need for a fifth orbiter before embarking on its development is the most "cost prudent" way to approach this problem.

QUESTION M-7:

If we were to add money to the FY 1985 budget to begin construction of the fifth orbiter, what is the funding increment that would be required to have no additional down time or loss of prime contractors and subcontractors?

ANSWER M-7:

The balance of funding between the in-house effort and subcontractors in the FY 1984 through FY 1986 timeframe retains many essential elements of the Orbiter build capability. However, the Downey/Palmdale assembly work force will be phasing down with the delivery of Atlantis, scheduled for December 1984. We cannot prevent some loss of production capability in the final assembly area. Operational and structural spares provisionings have been made to minimize the loss of capability with subcontractors. It is possible to increase the funding allocated for structural spares and thereby accelerate the schedule for structural spares components and to bring the components to a higher degree of completion by fabricating and installing more secondary structure parts. It is difficult to quantify the amount which could usefully be applied to the structural spares activity, but preliminary assessments indicate that approximately $30 Million to $50 Million would enable us to accomplish this higher degree of completion of the structural components.

QUESTION M-8:

We have been told by NASA that extending the Shuttle's on-orbit stay capability to in excess of 14 days would permit significant new research results to be achieved. Scientists have told us that such extensions would be "pure gold" and NASA has indicated that the cost of extending orbiter stay time to around 20 days could run as low as $78 million. Though the space station will of course permit much longer on orbit stay times, it will be limited to a single (probably 28° inclination) orbit. Would it not seem reasonable to make this modest investment in expending the orbiter's capability so that experimenters can conduct adequate research in polar or other orbits that are different from the one occupied by the space station?

ANSWER M-8:

We have for a number of years looked at the potential need for an extended duration orbiter and have identified three areas in which an expanded capability to 14 days could be useful:

(1)Vapor Solution Crystal Work
(2)Complete Solar Track-Entire Pass
(3)Full Earth Coverage, Polar Orbit

We believe the cost of developing the 15-20 day capability is more realistically sized at $100 Million - $250 Million, which we do not regard as a modest investment. Further study of the potential benefits and costs will be undertaken during the current fiscal year.

Question M-9:

Aerospace Safety Advisory Panel

Please elaborate on the most recent report of the Aerospace Safety Advisory Panel related to the Space Shuttle. Are you aware of any unresolved safety issues concerning the Space Shuttle?

Answer M-9:

The Aerospace Safety Advisory Panel in their 1983 Annual Report made several significant recommendations with regard to Shuttle Safety:

1. Augment quality assurance with motivational emphasis. The dominant goal should now be operational suitability rather than performance. This has been ongoing and is being further expanded.

2. Conduct a complete review of the landing gear. A complete brake review is now being performed by NASA and industry experts.

3. A logistic system requires an overall maintenance plan, a clearly defined Shuttle Processing Contractor (SPC) role, and should include all STS elements. Lockheed has been selected as the SPC contractor and has taken over full responsibility as of early February. These items are being addressed as Lockheed develops

procedures.

4. Expansion of the Shuttle operational envelope requires the derivation of a new set of loads and their validation through flight data. Validation began in July 1983 and is still in progress. Flight loads of 6.0 are being investigated and used at this time.

5. A major reduction in landing speed and improvement in pitch control should be explored. LaRC has researched use of canards and this option is still being evaluated by the program office.

These recommendations are under continuous review and the panel will be advised as further action is taken.

QUESTION M-10:

Are you concerned that the number of in-flight failures of critical space shuttle subsystems and components seems to be increasing with time?

ANSWER M-10:

We do not believe that the number of in-flight failures of critical Space Shuttle subsystems and components are increasing. The number of what could be classified as significant anomalies has remained relatively low and relatively constant over the flight program thus far.

There are some areas, e.g., brakes, that are experiencing problems on a recurring basis. These areas are being targeted for improvements/fixes and pose no major problems in the interim. We do expect that some failures will increase with time as hours of use begin to take its toll and life cycles are used up. The logistics programs now being implemented are designed to replace and or repair those items with neglible impact to the flight program.

QUESTION M-11:

Have the wing structures for Orbiters 103 and 104 been found inadequate or unsafe for operation from Vandenberg? What is being done to correct this problem? Will it affect flight schedule?

ANSWER M-11:

Due to higher than predicted ascent wing loads, as measured during OFT, the wing structures for Orbiters 103 and 104 were found to be inadequate for operational use. The wings are being modified for the early KSC flights through the addition of leading edge moment ties and trajectory shaping.

For later, high performance KSC and Vandenberg flights, it will be necessary to strengthen the basic wing structure for Orbiters 103 and 104. The basic definition of this modification will be completed later this month with detailed definition available in July 1984.

A series of aerodynamic fixes such as wing spoilers and attach structure fairings are also being evaluated as possible aids in wing load reduction.

It is not expected that the flight schedule will be affected as a result of the

wing modification. The wing modifications under consideration are in the nature of local structural strengthening up rather than replacement of primary members.

QUESTION M-12:

Why did the failures that occurred in two of the APUs during STS-9 never occur previously during ground testing?

Have you checked to see that there are no differences in ground testing procedures and actual flight procedures for any other systems or subsystems on the orbiter?

ANSWER M-12:

Two of the three STS-9 Auxiliary Power Units (APU's) developed fuel leaks which ignited during atmospheric entry and continued burning through landing. After shutdown, the resulting high temperatures caused detonations inside fuel system components, which damaged the hardware. The leaks came from stress cracks in the gas generator injector tubes, caused by extended exposure to a corrosive environment.

This never occurred previously during ground testing, because the corrosive attack is relatively slow. The two failures on STS-9 occurred after fuel exposure times of 25 months and 36 months, respectively. The longest exposure time for a ground qualification unit was 18 months.

As a result of the APU experience, all material applications in hypergolic systems are being reassessed with respect to details of manufacturing processes and their exposure to potentially corrosive residues. Specific "high time" components will be disassembled and evaluated.

We have simulators and ground testing procedures that check all systems on the orbiter individually as well as in an integrated, operating system level environment. In addition to this, we perform extensive mathematical model analysis of the systems and their components.

There are, however, some conditions that cannot be fully simulated, such as zero gravity and certain life cycle issues, but we feel the testing programs are as close to actual usage conditions as is feasible and that they are adequate.

QUESTION M-13:

What is being done to correct the continuing brake problems on the Orbiter?

ANSWER M-13:

A series of improvements have been made in the braking system with the result that the degree of brake damage has decreased on recent flights. The specific improvements incorporated include the installation of a steel spacer, or saddle, between the brake assembly and axle to prevent brake damage due to axle deflection. Steel caps have been installed on the beryllium rotors and stators to prevent deformation of the drive lugs. Manufacturing quality controls and inspections have been strengthened to eliminate minutely cracked carbon liner retaining washers and undersized

thermal slots in the rotors and stators. A deceleration readout has been added to the Heads Up Display (HUD) to aid the crew in brake application.

A team of industry and government engineering experts, including those with commercial transport experience, met in January 1984 to review the braking system and suggest further improvements. Industry representatives included Bendix, Boeing, General Dynamics, Grumman, Lockheed and Northrop. Government representatives included NASA and Air Force. The experts have provided us with their recommendations which are currently under evaluation. In accordance with one of these recommendations, it is planned to instrument selected flight vehicle brake assemblies to determine the exact cause of the remaining brake problem.

We are also carefully evaluating the recommendations of the Aerospace Safety Advisory Panel as described in their most recent report.

The braking system problem is a reuse, rather than a safety-of-flight, issue. The brakes perform their braking function but require reconditioning on some of the elements following flight. We have adequate spare parts in flow to support the on-going flight program, pending final resolution of the brake reuse problem.

QUESTION M-14:

Are you convinced that you fully understand the reasons for the unusually high erosion rates that occurred in the booster nozzles during the flight of STS-8?

What is being done to ensure that it does not happen again?

ANSWER M-14:

A thorough investigation, including special tests was conducted to determine the cause of the high erosion which occurred on the SRM nozzle. These investigations revealed that the STS-8 nozzle experienced spalling of the carbon phenolic material. The factors that produced this problem included material with higher than nominal volatile content; change in temperature and pressure during the cure cycle; and loss of vacuum during the cure cycle. Corrective actions have been initiated which includes the use of low volatile content material, change in the cure cycle, and ensuring that proper vacuum is maintained.

QUESTION M-15:

Does NASA have an adequate review procedure for deciding when engineering or process changes can be flown without first testing the changes on the ground?

ANSWER M-15:

Yes, NASA does have a rigorous procedure involving all changes before the changes are approved. There are three levels of control. Any change must be processed at a Project Level Change Control Board. This board would assess the nature of the change and determine whether the change can be qualified by similarity, analysis, or if it requires specific ground testing. All changes that impact the Shuttle system interfaces are also reviewed by an

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Integration Board, and dependent upon the significance of the change on cost and/or criticality, the change is also approved by a Headquarters Review Board.

QUESTION M-16:

Does NASA plan to continue 100 percent x-ray inspection of the solid rocket booster motor segments?

If not:

- Why?
- Has this change been discussed with the Aerospace Safety Advisory Panel? When will it?
- Has this change been discussed with the Air Force ordnance safety people at Cape Canaveral? When will it?

ANSWER M-16:

During the solid rocket motor (SRM) DDT&E Program, x-ray inspection of motor propellant grains provided 100% coverage. This included the seven static fired units and flight articles through STS-5. Also, the high performance motor static firings (2), and the first flight article (STS-8), were x-rayed. The radiographic inspection was used to validate processing techniques and controls. Although no formal report was issued, analysis of DDT&E results and flight experience indicated that based on the successful demonstration to control porosity in the SRM propellant grain, first stage Minuteman production experience (over 2,900 units), and Morton Thiokol's recommendation, MSFC has reduced the x-ray inspection requirements as follows:

a. All aft segments are x-rayed in the propellant hand trim area, which provides for nozzle clearance.

b. All segments are x-rayed following; (1) process anomaly; (2) process change; and (3) design change.

There have been some discussions with the Aerospace Safety Advisory Panel on this change. As a follow-up, the Aerospace Safety Panel is scheduling a meeting in July at the MSFC to further review in depth the results of this change.

The Air Force requires its users to discuss any design aspects with respect to destruct systems. The SRM range safety system has been assessed in detail by the Air Force and they have approved the system for operations. There is no requirement to discuss with the Air Force ordnance personnel any design modifications or factory inspection procedures that do not impact the destruct systems design or safety adequacy.

QUESTION M-17:

How does the design factor of safety for the solid rocket booster compare with that for Minuteman?

ANSWER M-17:

As required for all manned space flight hardware, the minimum factor of

safety (F.S.) for the SRB is 1.4. The Minuteman had two build cycles - Wing I and Wing II. The F.S. on Wing I cases was 1.25, and the F.S. for Wing II procurement was reduced to 1.15.

QUESTION M-18:

What is NASA's estimate of the probability of occurrence of solid rocket booster failure that would result in the loss of an Orbiter?

Do Air Force Range Safety experts at Cape Canaveral agree with these estimates?

Can you account for the differences?

ANSWER M-18:

Since the Shuttle Vehicle is the first of its kind, valid historical statistical data did not exist to permit meaningful probability of failure studies during the program development phase. Extensive qualitative analyses were, however, performed to identify critical hardware and the design requirements, and safety factors were established for each major area. Manufacturing procedures were established and critical processes were identified and implemented to assure control and repeatability of each subsystem. Every step humanly possible has been taken to preclude failure of critical SRB hardware.

One such analysis was "The Failure Mode and Effect Analysis" and from this analysis was developed a Critical Items List (CIL). The CIL identified those hardware failure modes, and their causes, that could cause loss of Shuttle and/or life, and for each, a rationale for retention was developed which is defined below:

Rationale for Retention - A summary of the rationale for retaining the critical item including the following:

a. Design features, safety factors, and analyses performed which reduce the probability of failure occurrence.

b. Testing performed which demonstrates the capability of the component to perform its intended function.

c. Inspections performed which assure the quality of components and conformance to design requirements.

Even though specific reliability studies were not performed at the beginning of the program to establish probabilities of failures, it is a design and manufacturing goal to have zero failures. And, our demonstrated success to date has been 9 successful ground static tests and 20 successful flight motors.

Failure mode and effects analyses (FMEA's) have been defined for all Shuttle critical events. The Air Force Range Safety experts were provided with these analyses. In any areas where they felt it could impact the range safety destruct system, reviews have been conducted and resolved with them. There are no open issues, and both NASA and the Air Force are satisfied with the failure modes and the methods used to either eliminate or minimize these effects.

QUESTION M-19:

If there is a major problem with one or both of the solid rocket boosters during a launch, is it currently possible to either eject the motors while they are burning or terminate their thrust?

Would it be feasible to redesign them to do either or both of these things?

Has the Aerospace Safety Advisory Panel addressed this subject? What were their findings?

ANSWER M-19:

There is no way at this time to either eject the motors while they are burning or to terminate their thrust (unless the range destruct system is utilized which would be catastrophic to the Orbiter during launch).

It would not be feasible to redesign the motors to separate the boosters at nominal thrust levels, but it is feasible to terminate thrust. Thrust termination is not incorporated for various reasons including the fact that with manned flight, there are concerns that in the event the thrust termination was initiated erroneously, the mission and/or astronaut life could be in peril.

The Aerospace Safety Advisory Panel has addressed this subject. Their conclusion was in concurrence with NASA design to depend upon product quality assurance and design suitability. The Shuttle program has a continuing process to identify all failure modes and impose specific design requirements to minimize these failure modes. As an example, the propellants used in the motor have been proven in previous solid rocket programs, extra insulation is provided to prevent any case burn-through and a thorough development and qualification test program was completed.

QUESTION M-20:

We all realize the critical importance of maintaining a robust supply of spare and repair parts if the Shuttle is to support the manifest without major delays.

a. What is NASA doing to ensure that an adequate supply of spares will be available when needed?

b. Is the FY 85 budgetary request for STS spares and logistics support fully adequate, or should it be enhanced? How much?

c. In past years, NASA has tended to use the spares budget as a "management reserve". Will this tendency be stopped?

d. What is being done to ensure that NASA does not have the same spares costs problems that the Defense Department has been having recently?

ANSWER M-20:

a. NASA has budgeted the necessary funds and manpower to ensure

an adequate supply of spares exists based on current projections. In some instances, in order to preserve production capability, NASA has purchased spares which exceed the current projected near term needs. Spares is an area continuously reviewed for adequacy as the flight rate increases and equipment history is gathered.

b. The FY 1985 budget request for STS spares and logistics support is adequate based on current data and predictions.

c. There are no plans to use spares budget as a management reserve. All spares budget dollars will be needed to sustain our projected flight program. In FY 83, we budgeted and spent $270M total including spare engines.

d. Sensitivity to controlling spares costs is continually being reinforced within NASA. Actions currently underway are:

1. Multi-division task group formed at prime contractor to examine internal parts acquisition process and recommend improvements where necessary. (Recommendations due late March.)

2. Bring historical pricing records up to date. New prices which exceed old prices by a certain percentage will be automatically flagged.

3. By means of desk instructions, pricing classes, distribution of spares "horror stories" and other educational material, the sensitivity to efficient pricing is continually reinforced.

QUESTION M-21:

As of late last year, only 43 civil services employees at the Johnson Space Center were involved in overseeing the STS logistics system.

a. Do you believe that this is an adequate staffing level?

b. Are you concerned that none of these people are logisticians (they are all engineers)?

c. What is being done to correct these deficiencies?

ANSWER M-21:

a. We believe that additional staffing would provide better logistics support. The plan is to increase from the current level of 43 to 58 by April 1984

b. Although our "logistics engineers" are not classified as logisticians, in order to perform their previous assignments, they had to utilize the skills of a logistician. For example, since manned spaceflight began it has been supported by mission control centers. These centers had to be designed, developed, upgraded and maintained. These engineers were responsible to insure that spare parts, maintenance capability, transportation, etc. (typical logistic functions) were available when needed.

c. Using engineers in logistics is not considered by NASA as a deficiency. NASA differs from DOD and airlines in that we have never had

enough of the same systems to require a separate and dedicated logistics organization. However, within NASA, in order to function effectively, the functions performed by logistic organizations have been and are performed within various elements of the NASA Centers.

QUESTION M-22:

The only logistician working on the STS program at NASA Headquarters is a single Lt. Colonel on loan from the Pentagon. Does this really provide adequate oversight of this important area or a strong enough logistics voice within senior management circles? What will be done to correct the problem?

ANSWER M-22:

In addition to the Pentagon detailees, several logistics engineers are working either full or part time at NASA Headquarters in Logistics. Another full-time senior logistician will be joining NASA in April. This will provide adequate oversight of our logistics program for the present.

QUESTION M-23:

Given that most of NASA's professional logisticians are located at the Kennedy Space Center, wouldn't it seem reasonable to move Shuttle logistics oversight to that facility?

Why is Johnson Space Center resisting such a move?

ANSWER M-23:

The Johnson Space Center supports the concept of a logistics management transfer to the Kennedy Space Center. The exact timing of this transition is being planned at this time.

QUESTION M-24:

Are there still some elements of the STS that are not adequately funded or facilitized to reach a flight rate of 24 launches per year? If so, what are they? What is being done to correct this situation?

ANSWER M-24:

With perhaps one exception, the mission operations and training capability required to support 24 flights per year at the Johnson Space Center including facilities and equipment is provided for in the FY 1985 budget projection. However, recent experience in Shuttle Training Aircraft (STA) training indicates that a fourth STA may be required due to the need for more crew training than previously believed necessary.

At KSC sufficient capability currently is budgeted to achieve at least 20 flights/year for Shuttle processing. Payload processing capability is affected by the mix and scheduling of payloads and there may be some deficiencies in this area.

The capability to support a flight rate of 24/year currently does not exist for the External Tank and Solid Rocket Booster projects. However, planning and

funding requests are in place to insure the capability to support a flight rate of 24 per year by FY 1989.

QUESTION M-25:

Last December, the NASA Advisory Council made a strong recommendation that the operating budgets, facilities, and personnel required to support the Space Shuttle be "fenced" from the rest of NASA. It was argued that such an action would: speed the transition to more efficient operations; help reduce costs; and ease the eventual transfer of STS operations to the private sector or some new governmental operating agency. What is NASA's position on this recommendation?

ANSWER M-25:

Although the Shuttle program has successfully entered the operational era by demonstrating its reliability and versatility, among other factors the operational goal of achieving and sustaining the desired flight rate is sufficiently distant to preclude an organizational change of this nature at this time. From at least a program maturity standpoint, the current organizational structure within NASA should remain intact to insure that a stable and dependable system is provided.

Several factors lead to this conclusion:

- o We have yet to complete the orbiter fleet and modifications to Columbia remain to be done.
- o The complete set of ground support and launch site equipment is over two years away from readiness to support the desired turnaround intervals.
- o Cargo/Shuttle interface processes require increased standardization.
- o The maintenance and spares program for the higher flight rates is not yet in place.
- o The main engine still requires extensive maintenance and development of an acceptable design life has not yet been accomplished.

In light of these factors, plus the problems experienced during the first few operational flights, NASA believes that the current budget structure, which is divided between the Research and Development appropriation containing Space Transportation Capability Development and the Spaceflight, Control, and Data Communications appropriation containing Shuttle. Production and Operations Capability and Space Transportation Operations, provides the appropriate level of funding separation.

With regard to reorganization to increase efficiency and reduce costs, major steps have been taken at the operating level by consolidating the base operations and launch processing activities at KSC under two single contractors. Also, consolidating the JSC multi-contractor operations is being planned. However, any move to reorganize the current structure for the purpose of transferring STS operations outside of NASA would be premature, for a number of reasons including an acceptable level of maturity and stability.

Question M-26:

Quasi-Government STS Operating Corporation: Some people have suggested that a quasi-government corporation with a board of directors chosen by NASA, DOD, and commercial users be created to operate the Space Shuttle. What is your view of this proposal?

Answer M-26:

Such a quasi-government corporation is one of the alternatives which have been considered by independent evaluations conducted by DOD, NASA, OSTP, & others. Each of these independent evaluations has concluded that the STS for the near term should be continued under the present institutional arrangements. I agree with these evaluations which recommend that the Shuttle continue to be managed in the near term under the existing NASA institution while retaining the flexibility to evolve toward a different institutional arrangement in the long term. The specific alternative of a quasi-government corporation as the operating organization for the Shuttle could provide an opportunity to attract private investment in the STS, increased flexibility, and the opportunity to operate in accordance with business principles. But there is also a potential disadvantage in this alternative in the sense that this will require an increase in STS price as a result of the necessity of providing an appropriate return on investment.

QUESTION M-27:

NASA seems to be in the mode of recompeting all aspects of the STS program. Does it really make sense to recompete the contract for a company that is performing above specification, ahead of schedule, and below cost? If not, what standards do you think should be set to guide the agency in determining when it is appropriate to recompete contracts?

ANSWER M-27:

The possibility of recompetition has always been an integral part of our long range procurement strategy on all of our contracts. We do not want to make long term commitments that could preclude our achieving even greater savings through creative and innovative techniques/processes and cost applications. If we find through studies that savings could be gained without degradation of performance, while maintaining reliability and safety, we would want to pursue those possibilities.

The size of the job in terms of its scope and proposed length in time should be sufficient enough to make recompetition worthwhile. The timing of recompetition is of importance. It should be introduced when the configuration is set and the majority of the development activity has been accomplished and costs of transition could be minimized. Planned production rates should also be somewhat stabilized, so that investment costs can be accurately sized by the prospective competitors especially for such things as facilities, tooling and qualification of manufacturing processes. The capability and performance of the incumbent contractor would be significant determinants in any competition evaluation.

QUESTION 28:

We understand that the Marshall Space Flight Center has recommended that the external tank contract not be recompeted. Have you reached a decision regarding recompetition of the external tank?

- If not, when will you?
- If yes, what is that decision?

ANSWER M-28:

No decision has yet been made on recompetition of the external tank. For some time, we have been exploring a number of recompetition scenarios with the external tank and Center management. A joint meeting to further discuss viable options has been scheduled for later this month, March 1984. More detailed studies must be made prior to making any decision. It is anticipated that such studies will last until the end of 1984 and possibly longer.

Question M-29:

Space Shuttle Main Engines: We understand that NASA is undertaking a major new R&D program for the Space Shuttle Main Engine.

a. Please describe the status and plans for this program.
b. When will each phase be completed?
c. What will be the cost of each phase?
d. What is known about the failure that occurred to the phase II R&D engine last week?
e. What will be the cost of requalifying the "Phase III" design changes into existing engines?

Answer M-29:

Development and certification of the SSME for full power level (FPL) operation revealed deficiencies in the design relative to hardware life and performance margin. These deficiencies were centered exclusively in the high pressure fuel turbopump (HPFTP) and high pressure oxidizer turbopumps (HPOTP). The new development activity is planned in two parts. The Phase II efforts (Phase I consists of the current design being used for today's flight operations) are designed to (1) increase the stability margin of the HPOTP, (2) reduce the turbine operating temperature of the HPFTP, and (3) reduce opera-tional costs by increasing both the operational life of the pump and by increasing the time between unplanned replacements. The Phase II development will be completed about mid FY 1986 with completion of an engine certification test series. The cost of Phase II is expected to be about $270 million.

The longer term Phase III activity is directed at increasing the SSME operating margins and thus improving the safety and reliability of the SSME. The approach of the Phase III effort is to decrease the loads on the high pressure pumps by decreasing the pressure drop in the hot gas circuits and by increasing the area of the main combustion chamber throat. Alternative design and new hardware sources will be explored by means of several study contracts. The Phase III development effort is underway and testing will be started early in the second quarter of FY 1985 and the

certification will be completed approximately 3 years later. The expected costs to requalify the Phase III configured engine are estimated to be about $100 million. The unit cost of retrofitting the Phase III design changes into the SSME is difficult to estimate since the design changes are not known at this time. A worse case retrofit would consist of a completely new powerhead design, a new oxidizer heat exchanger, and the wide throat main combustion chamber. The costs of including these new parts into an existing engine would be approximately $7 million each.

The analysis of the recent (2/14/84) engine failure has not yet been completed and the root cause of the failure has not yet been identified. However, it is known that the immediate cause of the failure was the sudden stoppage of the high pressure fuel pump which resulted in the loss of hydrogen coolant to other parts of the SSME and in an oxidizer-rich shutdown. The HPFTP stoppage appears to have resulted from the collapse of the pump's turnaround duct coolant liner and the resulting blockage of the hot gas path through the turbine section of the HPFTP. It is known from test data that pressure in the coolant liner passage increased just before the failure, but the source of that pressure increase is still not known.

QUESTION 30:

Filament Wound Case: Regarding the project to develop a filament wound case for the solid rocket booster:

a. Please summarize the current status of the project.

b. What will be the cost and schedule impacts of the dropped case accident that recently occurred?

c. Do you think you will still be able to meet the planned launch date for the first filament wound case boosters?

d. Will the dropped case be used for the planned structural tests at the Marshall Space Flight Center or will it be replaced?

ANSWER 30:

a. The design phase of the filament wound case (FWC) project has been essentially completed. The Critical Design Review for the case was completed in February 1984, with no major design deficiencies identified. Also, hydrotest of the flight configuration of the aft segment was completed on February 28, 1984, demonstrating structural integrity at the required factor of safety of 1.4. All segments of the first static firing motor (DM-6) and the structural verification test article (STA-2) have been wound and are in various stages of completion. Winding of the forward segment of the second static firing motor (DM-7) is in progress. Current program milestones have been established as follows:

- Delivery of structural verification test article (STA-2) to MSFC 9/15/84
- Completion of critical STA-2 structural tests for initial Vandenberg launch 4/30/85
- Development Motor test firing (DM-6) 11/16/84

-	Development Motor test firing (DM-7)	4/26/85
-	First Vandenberg Launch Site hardware delivery	4/21/85
-	Qualification Motor Test firing(QM-5)	8/23/85

b. The root cause of the handling incident, which occurred on January 11, 1984, was determined to be the lack of adequate procedures for use of the breakover tool to transition the case from vertical to horizontal position. As a result, all processing steps which require a handling operation were suspended, pending review of all FWC handling procedures being used by Hercules. This review was accomplished, and the Pneumagrip tool was repaired and placed back in operation on February 2, 1984, incurring approximately a three week schedule impact to manufacturing operations. Ultrasonic inspection and analysis of the dropped segment showed no damage to the composite. Costs associated with the incident have not been quantified, but should not be significant in terms of a program cost impact. Costs incurred are those associated with repair of the Pneumagrip tool, which were not major, and labor for review of handling procedures and evaluation of the condition of the FWC case segment involved in the incident.

c. A detailed assessment of the FWC Project schedule was completed by MSFC in January 1984, which took into account the impact of the handling incident. Although the project remains on an extremely tight schedule, delivery of the first flight set to VAFB by April 1985, is still believed to be achievable.

d. The metal adapter of the case segment involved in the handling incident incurred a slight permanent deformation in the area of impact. The unit is believed to be suitable for use in structural tests at MSFC, based upon inspections completed to date. Dimensional inspection of the ring mated to the composite and structural analyses of this condition are currently in progress and must be completed before verification of acceptability can be made.

QUESTION M-31:

STS Payload Lift Capability: Are you satisfied the Space Shuttle will be able to provide the lift capability required by heavy DOD payloads in sufficient time to meet the scheduled launch dates for these payloads? If not, what is being done to correct the problem?

ANSWER M-31:

Yes, we are satisfied that we can provide the lift capability consistent with our time-phased commitments to the DOD. Possible performance improvements and enhancements were studied and we are now embarked on a course to implement selected items in a timely manner.

Items that are currently planned or are underway are: main engine certification to 109 percent power level, development of filament wound case SRBs, incorporation of lightweight SRB nozzles, consumables loading

optimization, and propellant reserve reduction.

QUESTION M-32:

You testified last year that the total average cost for Shuttle flights in FY 1983 would be between $225 and $250 million. What will be the total average cost per flight in FY 1984?

Anwer M-32:

The average total cost per flight in FY 1984 is expected to be in the range of $225 to $250 million. It should be noted that the adjusted FY 1983 average cost was $375 million, largely as a consequence of the reduced number of flights made during FY 1983.

QUESTION M-33:

What do you expect the "additive" cost of each Shuttle flight to average in FY 1984? What were these costs in FY 1983?

Answer M-33:

The marginal cost reduction realized over time for eliminating a Shuttle flight in FY 1984 is about $50 Million - $75 Million. The lower end of this range represents a conservative estimate of the savings, and can be compared with the estimate for a cancelled FY 1983 flight of about $55 million.

QUESTION M-34:

Can you be specific regarding the makeup of the additive cost per flight in FY 1984?

Answer M-34:

Based on data furnished by the field centers, a conservative estimate of the marginal cost of a Shuttle flight in FY 1984 is comprised of the following: (dollars in millions):

Orbiter Spares and Overhaul	4
Main Engine Spares and Overhaul	2
External Tank	18
Solid Rocket Booster	21
Flight Operations	3
Launch Operations	2
Total	50

QUESTION M-35:

In your part of the FY 85 budget, there are almost $1.2 billion of reimbursable funds:

a. Can you submit for the record a breakout of these funds by source:

- Commercial
- Foreign

- DOD
- Other Governments

b. Can you please submit for the record a breakout of the distribution of the use of these funds that is as detailed as the budgetary tables that you supply for appropriated funds?

ANSWER M-35:

The anticipated reimbursements for FY 1985 are $1.180 billion as shown:

a.	By Source	1.180
	Commercial	.279
	Foreign	.091
	DOD	.760
	Other Government	.050
b.	By Budget Line Item	1.180
	Shuttle Production & Operational Capability	.177
	Shuttle Operations	.676
	Expendable Launch Vehicles	.097
	Upper Stages	.161
	Spacelab	.007
	Payload Operations and Support	.033
	Engineering and Technical Base	.029

QUESTION M-36:

Why does NASA continue to need the "management reserve" reflected by the $25 million in the "Changes and System Upgrading" account?

ANSWER M-36:

We are still early into the operational phase of the Shuttle program. Flight experience to date has identified a number of program elements that can or should be modified to improve turnaround times and operating efficiencies. It is anticipated that future items of this type will be identified as we continue our operational experience. The $25 million in the FY 1985 request is considered to be an adequate amount to do those things with the most promising paybacks.

QUESTION M-37:

Why is there a 78 percent increase in the funding level for STS Operations at NASA Headquarters?

ANSWER M-37:

Approximately 2/3 of the FY 1985 Headquarters funding for Shuttle Operations represent reserves that have not yet been allocated to the field centers. As we proceed through the year and problems are identified, these funds are then allocated to the appropriate projects. At this time the majority of the FY 1984 reserves have been distributed to the centers. This accounts for the apparent increase of 78% from FY 1984 to FY 1985.

QUESTION M-38:

Since 1983, there has been almost a 500% increase in the funding level at NASA Headquarters for "Shuttle Production and Operational Capability Development". Why?

ANSWER M-38:

The majority of the increase of approximately $78 million at Headquarters is related to the following: (1) A little over 50 percent of the FY 1985 request identified to NASA Headquarters represents reserves that have not yet been allocated to the field centers. These reserves are allocated to the field centers during the operating year as required. The FY 1983 amounts are actuals and thus, no longer contain any reserves. (2) Funds for the main engine technology program activities and the Advanced Extravehicular Mobility Unit (AEMU) are being managed out of Headquarters until there is better definition of the tasks to be assigned to which center. When these elements are defined, and as problems develop and reserves are distributed, the Headquarters funding will be reduced to a level consistent with the FY 1983 level.

QUESTION M-39:

Why is there a 23 percent decrease in STS Operations funding at the Kennedy Space Center given that there is a substantial increase in launch rate?

ANSWER M-39:

The increased reimbursable income for Shuttle standard services that is shared proportionally by all the elements of Shuttle Operations account for the decrease in direct appropriations for KSC from FY 1984 to FY 1985. The combination of these direct and reimbursable funds are approximately equal for FY 1984 and FY 1985. The substantial savings that have been realized in negotiations with the Shuttle Processing Contractor (SPC) allow us to meet the flight rate buildup with about the same level of funding as was required in FY 1984.

QUESTION M-40:

We understand that the Defense Department has cancelled one of its flights for FY 1984. How much will NASA save on this cancelled flight? What will happen to the funds?

ANSWER M-40:

The usual savings from a dropped flight are approximately $50-$75 million. Due to the lateness of this cancellation some of the flight planning activities have already occurred and these expenditures are lost. The net savings expected from this cancellation will be at the lower end of this range. Since the hardware is already built, these savings will be primarily in FY 1985 and FY 1986 where future hardware builds can be adjusted. Savings are estimated to be about $20 million dollars each year. Based on the MOA between NASA and DOD, the DOD has already paid NASA for this flight. As a result of the cancellation the DOD will receive a credit towards the flight charge for a DOD flight in FY 1986.

QUESTION M-41:

In the "Launch and Mission Support" part of your budget request, you mention a "Shuttle Post-Flight Data Reduction Facility".

a. What is this facility?
b. What will it do?
c. What will it cost?
d. When will it be available?

ANSWER M-41:

a. The Post-Flight Data Reduction Facility (PDRF) will be developed to provide near real-time automated data screening and processing. The purpose of the PDRF is to (1) meet the STS turnaround requirements and projected mission model by identifying to KSC within 24 hours (in most cases) after landing what need to be removed/replaced, calibrated, tested, etc.; (2) reduce manpower for real-time operations and analyses and for post-flight analyses. It will be located in an existing JSC facility.

b. The PDRF will (1) screen all parametric data for high interest detailed analysis; (2) automatically extract pre-processed and formated data; (3) compare current mission data with previous mission data for trend analysis, and (4) automatically identify mission anomalies.

c. The estimated PDRF cost through FY 1989 is approximately $30 million.

d. The initial operational capability date is under review.

QUESTION M-42:

What is the current status of NASA's efforts to commercialize ELVs?

ANSWER M-42:

Three companies submitted proposals to commercialize NASA's Expendable Delta and Atlas Centaur launch vehicle systems. General Dynamics Convair (GDC) proposed to take over the Atlas Centaur. Transpace Carriers proposed to take over the Delta vehicle system, and the Cyprus Corporation proposed to utilize some Delta vehicle materials and tooling to produce a commercial upper stage they are considering offering to STS customers.

The current status of actions taken consist of the General Dynamics Convair (GDC) being selected for operation of the Atlas Centaur program and information is being exchanged between NASA and GDC prior to negotiations. A draft agreement has been forwarded to GDC, and a response with initial negotiations is anticipated in early March 1984.

We have notified Transpace Carriers, Inc. (TCI) of our willingness to negotiate with TCI leading to a commercialization agreement for the Delta vehicle system. Information has been exchanged with TCI and negotiations have begun.

In the case of the Cyprus Corporation regarding access to certain Delta production equipment to be used to modify a second stage of Delta as an

upper stage with the Shuttle, steps are being taken by NASA to provide this access.

NASA will be fully responsive to the President's directive, including participation and coordination with the Department of Transportation (DOT) selected as the lead agency within the U.S. Government to encourage and facilitate commercial ELV activity by the U.S. private sector.

QUESTION M-43:

NASA has not requested funds for a fifth orbiter, saying that market projections do not show sufficient demand to support an expanded orbiter fleet.

How does ELV commercialization interact with NASA's decision not to seek funding for a fifth orbiter?

ANSWER M-43:

ELV commercialization is in the initial stages of development. The decision not to seek funding for a fifth orbiter was not a consideration related to ELV commercialization but one of timeliness and the fact that the current fleet of Shuttle Orbiters will provide sufficient capabilities to support our current flight planning requirements.

QUESTION M-44:

Is market demand sufficient to sustain a commercial ELV industry without some form of government support? If not, will NASA provide support to maintain a commercial ELV industry? What form of support will NASA provide (e.g., technical assistance, purchase of commercial ELV launches, access to NASA launch and tracking facilities, etc.)?

ANSWER M-44:

NASA is being fully responsive to the President's directive in cooperating and assisting in the commercialization of ELV's. It is anticipated that commercial ELV operation will require use of government launch or tracking facilities as well as production tooling and other support. Charges for this support will be assessed at least two ways. First, use of government tooling and equipment will be provided to the commercial operation for a use fee and a commitment to maintain, repair and replace tooling and equipment used. Secondly, support such as tracking and range support will be charged on a additive cost basis. No subsidization of this commercialization is being planned by NASA.

QUESTION M-45:

DOD is proceeding to develop its own ELV capability as a complementary system to the Shuttle. DOD wants to rely on commercially available ELVs in the short-term and on Shuttle derived ELVs for the long-term. This action appears counter to DOD's stated commitment to the Shuttle as its primary launch system.

a. As an Air Force officer on detail to NASA, do you feel that a conflict-of-interest exists that constrains you against speaking out on DOD

actions that jeopardizes the Shuttle and NASA's efforts?

b. In your view, why is DOD moving to sustain and expand ELV availability and what is your evaluation of this trend and its implications on the Shuttle?

c. Would a fifth orbiter satisfy DOD's need for expanded launch capabilities?

ANSWER M-45:

a. No, I do not. I personally believe in the Shuttle program and its place not only in our civilian efforts but also our defense efforts. Rather than a handicap, I see my position as having the advantage of knowing the military system and requirements and being in an excellent position to advocate the Shuttle program.

b. DOD has told us that they must ensure the availability of an adequate launch capability to provide access to space at all levels of conflict. The Honorable Edward C. Aldridge, Jr., Under Secretary of the Air Force, addressed this question in his February 23, 1984, statement before the Committee on Science and Technology, Subcommittee on Space Science and Applications, House of Representatives. The essence of DOD's argument is that they believe a complementary launch system (ELV) is needed as a "hedge against unforeseen technical and operational problems and the need for a launch system suited for operations in crisis and conflict situations."

We believe the Shuttle, with its built-in redundancy, the ability to examine (except for the external tank) all components after each flight, and the added information provided by the crews, make it the most reliable and flexible launch vehicle ever available to the United States.

If provision for an ELV capability for national security purposes is to be made, then NASA believes that a thorough analysis should be made of potential alternatives, such as a Shuttle-derived launch vehicle which could take advantage of more recent technology and permit the use of some of the same spares, launch facilities, and manpower.

The National Academy of Engineering is looking at the various options available for use of ELVs. Presentations by NASA and the DOD have been made on the studies concerning both Shuttle derived launch vehicles and modified existing expendable launch vehicles.

c. It is the DOD's position that the acquisition of the fifth Shuttle orbiter does not improve the launch assurance for high priority DOD missions because these missions will be flown on the existing orbiters whenever national security needs dictate the exercise of preemption rights. The addition of the fifth orbiter would not satisfy these concerns and they have stated so publicly.

QUESTION M-46:

The NASA Advisory Council, in a November 17, 1983, report to NASA, recommended that NASA retain an ELV launch capability until the Shuttle

becomes fully operational. The Council argued that NASA needs ELVs to:

- Assure access to space for commercial customers should the Shuttle experience major delays;

- Provide a surge capability for periods when launch demand exceeds Shuttle capability; and

- Provide an option to a dedicated Shuttle flight for placing a small, Delta-class payload into orbit from Vandenberg.

What is NASA's response to the NASA Advisory Council's recommendation to retain an ELV capability within NASA?

ANSWER M-46:

NASA will continue, on a reimbursable basis, an ELV capability at least through the mid-late 1980's, while supporting potential commercial efforts. The Delta launch vehicle production will continue through 1984 for launches through mid-1986, and there will be available two completed Delta vehicles along with residual Delta hardware for additional vehicles. Atlas Centaur production will continue through 1985 for launches through mid-1987. In addition, the USAF Atlas vehicle will support DOD/NASA launches from Vandenberg AFB at least until the first flight of Shuttle from the West Coast launch site.

NASA is currently negotiating agreements with General Dynamics Convair and Transpace Carriers, Inc., who have been recently selected in open competition to be sole operators of the commercial Atlas Centaur and the Delta launch vehicle.

QUESTION M-47:

Last year, the Committee directed NASA to develop a comprehensive marketing plan for the Shuttle using outside contractor support. This marketing plan was to be submitted to Congress on October 1, 1983.

a. What is the status of the Shuttle marketing plan that the Congress directed NASA to prepare?

b. How is NASA proceeding to develop this Shuttle marketing plan and what specific elements will it contain?

c. What organizational structure should be established to market the Shuttle? Should NASA perform the function or would it be more effective to have another agency with marketing experience (e.g., Commerce Department) or a contractor market the Shuttle?

ANSWER 47:

a. A draft of the STS Marketing Plan has been through one cycle of internal NASA review and coordination. It is now being rewritten to incorporate the comments made during the review process.

b. A marketing plan is being prepared with the help of industry experts in marketing and assistance from the Harvard University Graduate

School of Business and the Office of Management and Budget.

c. At present NASA is performing the primary "marketing" function for the Shuttle, because this requires a great deal of technical knowledge that is currently only available within NASA. We are working with other agencies to tap their expertise. In particular, the Commerce Department is providing assistance through its Foreign Commercial Service and the State Department through foreign Embassies.

QUESTION M-48:

On the last Shuttle mission, two commercial satellites (Westar and Palapa) were lost due to PAM failures.

a. What caused the recent PAM failures which resulted in the loss of two satellites, and is NASA doing anything to assist manufacturer in correcting these problems?

b. Does NASA have any plans to recover the Westar and Palapa satellites lost on the last Shuttle flight? Could a Shuttle mission to recover these satellites be used to demonstrate the Shuttle's capabilities? What are the pros and cons of such a mission?

c. Does NASA have a formalized procedure to assist customers prior to flights in making technically based decisions about proceeding with a launch of a customer payload?

ANSWER 48:

a. The cause of the PAM failures is being investigated by McDonnell Douglas Corporation (MDC) and Thiokol with NASA assistance as requested. The investigation is still underway and cause of failure is not yet reported.

b. The subject of retrieval of the two payloads (Westar VI and Palapa B-2) is a sensitive one at this time because of the ongoing activities between Western Union and the Indonesian Government with the insurance companies involved.

NASA has not been requested by either customer to initiate any retrieval activity. However, recognizing that the question has been raised by other sources and that sometime in the near future NASA could be requested to initiate such activity, we have done some preliminary studies. Disregarding legality and ownership issues, these preliminary studies indicate that retrieval of both spacecraft is possible provided that the spacecraft apogee motor can be safed, that the spacecraft can be despun and that there is some fixture which can serve as a grapple fixture for the astronaut using an EMU as well as the manipulator arm.

c. Prior to a Shuttle flight NASA and the customer develop a set of formal "mission rules" to govern the Shuttle crew's activity involving the customer's payload during a Shuttle flight. These rules define various probable scenarios and the corresponding required crew actions are developed to handle situations which would require immediate action on the part of the Shuttle crew. In addition, customers generally develop similar contingency plans for dealing with problems that might occur with their own payload during the Shuttle flight and particularly after deployment from the

Shuttle. Although there is no formalized procedure for NASA involvement in technically based decisions that pertain solely to the customer's payload, NASA has always offered whatever technical assistance could reasonably be provided upon the request for assistance from the customer. Further, NASA has offerred some alternate flight plan options to allow more time for the customer to examine a problem.

QUESTION M-49:

The Inertial Upper Stage (IUS) developed by the Air Force has experienced problems on the two missions it was used. The IUS will not be flown again until development problems have been corrected.

a. What is NASA's assessment of the progress being made to resolve the problems with the IUS?

b. If the IUS is not ready for the next scheduled TDRSS launch, will NASA consider using a commercial upper stage such as the one that will be available in 1987 from Orbital Sciences Corporation?

ANSWER M-49:

a. A number of flight anomalies were experienced during the flight of IUS-1/TDRS-A which was launched on April 4, 1983. All except the control anomaly which caused the vehicle/spacecraft stack to tumble were very quickly diagnosed and design and/or software solutions identified. The control anomaly was also the only one which would have prevented mission success.

Early in the investigation, it was determined that the techroll seal in the second stage nozzle collapsed and thus prevented the nozzle from vectoring properly. The ensuing time has been spent in determining the reason for the techroll seal failure and devising engineering remedies for the failure. This effort has included the fabrication of a specially instrumented motor which was test fired in December of last year. Since that time, the test data has been carefully analyzed and the motor dissected to assist in the determination of the cause of the failure. A second test motor firing was conducted on March 3, 1984.

Selection of design changes has been finalized. A witness firing of the second stage motor scheduled for August would incorporate all design changes. This has been a lengthy, painstaking process which it is believed will culminate in a redesign of the faulty parts and a fully operable Upper Stage. An IUS ready to launch capability is projected for November of 1984 with the next TDRSS launch occurring in the first quarter 1985.

b. If additional problems develop that cause IUS launch availability to slip into the 1987 time period, alternative vehicles such as Centaur and the Orbital Sciences Corporation upper stage (OSC/AMS) could be evaluated.

QUESTION M-50:

What is the current status of the Shuttle/Centaur development program? Will it be ready for the first scheduled launch in 1987?

ANSWER M-50:

In FY 1983, we completed the Critical Design Review on the G Prime vehicle and Centaur integrated support structure, and the preliminary design revew on the G Prime flight vehicle. In FY 1984, we will conduct the preliminary design review on the G flight vehicle. The program was generally on plan through FY 1983, with the exception of the redesign of the Centaur integrated support structure. All milestones are being met, and while the schedule remains tight, we are definitely able to support the NASA Galileo and International Solar Polar missions in 1986.

QUESTION M-51:

What is NASA's evaluation of the effectiveness of the current pricing policy in attracting customers to the Shuttle?

ANSWER M-51:

We believe the current pricing policy (for launches in FY 1986 through FY 1988) has been effective in helping to attract foreign and commercial communication satellite system customers. The Shuttle pricing policy has been publicly stated by NASA. In contrast, the Ariane's pricing is not publicly available and apparently is subject to negotiation with each customer. In several cases where we were able to compare launch prices, the Ariane launch price was slightly lower than Shuttle's, even after adjusting for higher insurance rates.

In light of the relatively small price differential, we believe customers have chosen Shuttle because of NASA's 25 years of experience in the launch service area and because NASA was better able to meet their launch needs.

QUESTION M-52:

When will NASA begin to develop a new Shuttle pricing policy for FY 1988 and beyond and what factors are likely to drive its development? Is NASA considering an extension of the Phase II Shuttle pricing policy?

ANSWER M-52:

The price for launches in FY 1988 is already established under the current pricing policy for launches in FY 1986-1988. Beyond 1988, the President has stated that the Administration's intent is to establish a full cost recovery policy for commercial and foreign STS flight operations. We are now examining our current experience with Space Shuttle operational costs as a basis for projecting the estimated costs for launches in 1989.

QUESTION M-53:

Please describe the current agreement between NASA and DOD regarding prices that will be charged DOD for the Shuttle. Is this pricing agreement fair to NASA and, if not, how should it be changed?

ANSWER M-53:

The current NASA/DOD agreements on Shuttle use contain the following provisions for prices of DOD launches:

-DOD will pay $16.0 million (FY 1975 $) for Materials and Services for all DOD launches in FY 1984 and FY 1985.

-DOD will pay a rate currently fixed at $29.8 million (FY 1975 $) per DOD launch for FY 1986 through FY 1988.

These pricing policies provide the framework and conditions for appropriate reimbursements by DOD for STS flight charges. They were developed in recognition of the major investment DOD is making in the STS program.

QUESTION M-54:

Will DOD be charged higher fees when one of their launches uses a non-reusable filament wound SRB? If not, will NASA lose money on such flights?

ANSWER M-54:

Because the added performance is part of a capability commitment made by NASA, DOD is not being charged an additional amount for using the filament wound case (FWC) SRB's on their flights.

The FWC boosters are manifested as needed by NASA to meet baseline NASA performance commitments for STS missions. While DOD mission requirements fall within these NASA performance commitments, not all DOD missions require the FWC boosters.

QUESTION M-55:

It was reported in Aviation Week magazine recently that NASA has just instituted a a procedure of requiring that all photographs of the Earth taken from the Space Shuttle go through a security review by the Defense Liaison Office before they are released to the public. What do you think of this new policy?

ANSWER M-55:

The statement that NASA has instituted a procedure of requiring that all photographs of the Earth taken from the Space Shuttle go through a security review by the Defense Liaison Office before they are released to the public is misleading.

Anticipation of the increased amount of photography expected to result from the growing number of scheduled Shuttle flights led to a NASA Headquarters review of procedures for release of this information into the public domain. This review concluded that a prudent public affairs policy required the identification of photographs prior to public release with a better system for organizing the photos by broad subject category.

As in the past, NASA's objective is expeditious release of its imagery. No photography has been withheld from public disclosure.

QUESTION M-56:

a. Please describe the Spartan program and its objectives and funding for FY 85.

b. When will the Spartan program be completed and sounding rocket payloads be flown on the Shuttle?

c. How would you respond to the scientific community's concern that NASA is not giving this program adequate attention and that the program is underfunded?

ANSWER M-56:

a. The Spartan program consists of the development of low-cost sounding rocket-type payloads which will be flown on the Space Shuttle to provide more flight opportunities to the science community at a relatively low cost. The sounding rocket program has consistently provided the physics and astronomy community with the means to flight test instruments which are being developed for later use on a Shuttle/Spacelab mission or space probe, and for calibrating and obtaining vertical profiles in concert with current orbiting spacecraft. The Spartan program is designed to allow longer flight time of some of this instrumentation; particularly the instruments which are used to calibrate and obtain vertical profiles in concert with current orbiting spacecraft. The current FY 1985 planned funding range is $5-7 million.

b. The first "Spartan" payload is scheduled for flight on the Space Shuttle later this year. The "Spartan" program is envisioned as an ongoing program which will be reevaluated each fiscal year; therefore, there is currently no projected time of completion for the program.

c. A great deal of emphasis has been placed on the "Spartan" program within NASA as a means of providing more flight opportunities to the scientific community. I believe the "Spartan" program is receiving an appropriate level of funding; however, we will continue to try to define more low-cost flight opportunities for the respective scientific communities.

QUESTION M-57:

What would be the impact of a $50 million deletion from the FY 1985 STS Operations Budget?

ANSWER M-57:

A $50 million deletion would reduce the allocated flexibility to respond to anomalies on equipment failures (such as those experienced this year), from 3 percent to 1.5 percent of the budget in a year when up to eleven (11) missions from KSC are scheduled. A reduced ability to protect the launch schedule, due to the lack of adequate reserves, could cause a delay such that our credibility in the user community would be damaged.

QUESTION M-58:

Is serious consideration being given to permitting foreign countries to develop the OMV as a means of providing foreign participation in the Space Station Programs?

Given the investment that U.S. companies have made in this program, and the possible economic and national security implications of transferring this

technology to foreign countries, would a decision to permit foreign countries to develop the OMV be wise?

ANSWER M-58:

The President's call for international participation in the Space Station project is currently the subject of exploratory discussions in which Mr. Beggs will be meeting with potential international partners. While no decisions or agreements have been reached, we are exploring a wide range of options. The OMV is neither excluded nor specifically included in those discussions.

It should be recalled, though, that OMV is perceived as a potential element of the Space Station infrastructure; it is also envisioned as a possibly desirable augmentation to the STS, to expanding its operational envelope, and allowing greater manifesting options in service of a wide range of Shuttle-launched payloads. Any potential foreign involvement will need to be examined in light of these STS applications as well as those for Space Station. All options for international cooperation are carefully weighed against industrial, economic, security and technology transfer implications; OMV is no exception.

QUESTION M-59:

I understand that NASA has studied extensively the need for additional orbiters. Did your examinations include consideration of the loss or extended downtime of one of the four orbiters in the fleet? what were the results of that study? Can you provide us with a copy of that study?

ANSWER M-59:

The fifth orbiter production report has just recently been submitted to Congress. The conclusion of the report is consistent with NASA's previously stated position that the currently approved four orbiter fleet can support projected launch demands for at least the remainder of the decade. The area of launch assurance in the face of an Orbiter being out of service for an extended period is an area where support becomes marginal.

However, it is believed that such launch assurance could still adequately be maintained with one orbiter out by reprioritizing payloads, recombining of payloads and steps that would reduce turnaround for limited time frames.

The need to provide launch assurance and to maintain a base production capability was recognized as early as FY 1983, when funds were authorized to initiate procurement of structural spare components. These structural spares could be used as replacement parts for the current fleet or as major elements for a fifth orbiter sometime in the future.

QUESTION M-60:

In the case of conflicting needs for using the Shuttle, what would be the order of priorities—i.e., for national security missions, government R&D missions, private sector R&D missions, commercial satellite launches, foreign payloads, etc.?

ANSWER M-60:

In the event that a conflict arises in the utilization of the Space Shuttle the following prioritization will be in effect for Shuttle flights:

(1) Missions with national security implications.

(2) Missions with specific launch window requirements (e.g., planetary, Haley's comet, etc.).

(3) Reimbursable missions including other U.S. Government, foreign and U.S. commercial payloads.

(4) NASA research and development missions.

(5) Standby and ancillary payloads (e.g., Hitchhiker, GAS, SSIP, middeck, etc.).

QUESTION M-61:

In 1978, 29 payloads were received for space science experiments for Shuttle launches. What is the status of these?

ANSWER M-61:

In 1978, payload planning was in a state of rapid change and records from that period do not corroborate the specific number (29) of space science payloads referred to. In July 1979, there were 20 NASA and five non-NASA space science payloads booked for Shuttle flights in the period 1980 through 1984. Status of these is as follows:

Five have been flown (OSTA-1, OSS-1, OSTA-2, SPAS-01, Spacelab 1).
Four are scheduled in FY 1985 (LDEF, SMM Repair, OSTA-3, ERBS).
Six are scheduled in FY 1985 (Spacelab-2, and -3, Material Science-1 and -2, Earth Observation Mission 1 and Spacelab D-1).
Five are scheduled in FY 1986 (Space Telescope, Galileo, ISPM, Life Science Spacelab, ASTRO).
One is scheduled in FY 1987 (Astrophysics Spacelab).
Three GOES weather satellites (D, E, and F) were launched on Delta vehicles.
The Active Magnetosphere Particle Tracer Explorer is scheduled for launch on Delta later this year.

QUESTION M-62:

What would be the cost to the taxpayers of an orbiter production and operational support program as suggested by Dr. Lovelace?

ANSWER M-62:

Dr. Lovelace has suggested that NASA, jointly with its industrial team, define an orbiter production and operational support plan for a 15-20 year program. We have not yet conducted such a study but will be reviewing the suggestion as part of our long range planning effort, and will be glad to provide you our cost estimates when they are available.

QUESTION M-63:

What portion of the Space Tracking and Data Acquisition budget of $796 Million is related to shuttle flights?

ANSWER M-63:

Elements of the Space Tracking and Data Acquisition budget which support shuttle flights also support unmanned applications and scientific satellites. We maintain the general purpose networks to meet the varied requirements of all flight projects and programs. It is, therefore, difficult to quantify only Shuttle related costs. However, there are certain OSTDS shuttle unique costs such as STS dedicated operations at Dakar, Botswana, communications circuits and DOD tracking support services which are about 3% of the $796M budget.

QUESTION M-64:

Under Space Transportation Capability Development, there are three items: Upper Stages, Engineering and Technical Base, and Payload Operations and Support Equipment that total to $260 million for FY 1985. Is this all Shuttle related R&D?

Answer M-64:

Although the Upper Stages and Payload Operations and Support Equipment budget elements are clearly Shuttle-related R&D, the budget element called Engineering and Technical Base provides multi-program support. Based on the current workload at the Johnson Space Center, Marshall Space Flight Center, National Space Technologies Laboratory and Kennedy Space Center, the predominant benefitting program is the Space Shuttle, but Space Science and Applications and Space Research and Technology programs also are supported. A brief description of each budget element is provided below:

The Upper Stages FY 1985 request ($92 million) is primarily related to the development and production of the Centaur Stage to be used to launch satellites or planetary missions from the Shuttle. This budget also contains funds to procure the final IUS vehicle for NASA use from the DOD.

The Engineering and Technical Base (ETB) FY 1985 request ($106 million) provides the core capability to sustain the engineering and development base at the field centers to support all the STS programs. Although the specific core level of support differs from center to center due to programmatic and institutional differences, the ETB budget provides the funds to maintain a minimum level of support for institutional research and development facilities and services. Additional support requirements above the core levels are funded by the benefitting programs.

Payload Operations and Support Equipment ($62 million) provides unique hardware, analyses and launch site services to support STS missions - including management of the Solar Maximum Mission retrieval/repair; the development and acquisition of reusable ground support equipment required by payloads; and the operation of the Payload Operations Control Center (POCC) to command and control Shuttle and Spacelab attached payloads.

QUESTION M-65:

Can you provide us with a breakdown of the costs to date (by year in real year dollars) of the total investment in the Shuttle, including R&D program, facilities construction, orbiter procurement, and the allocation of Research and Program Management funds?

ANSWER M-65:

The total investment through FY 1983 for the Shuttle Program for these items is as follows (in billions of real year dollars):

Research and Development	10.078
Orbiter Procurement (procurement of 2 new Orbiters and modification of 2 bought in R&D)	3.194
Facilities Construction	.482
Research & Program Management	2.638

Annual phasing of funding is indicated on the enclosed Chart A.

QUESTION M-66:

How many missions over the next decade need an extended duration orbiter? What are these missions and their relative priorities? What would be the total cost per mission including orbiter modifications, the cost of the mission itself, and the crew and logistics support?

ANSWER M-66:

There are a number of scientific activities that would benefit from extended Shuttle missions; however, most of the missions designed for long duration are Spacelab missions which, as originally conceived, were to be proof-of-concept missions before committing to longer space exposure via free flying spacecraft or Space Station missions. Several endeavors which would particularly benefit from extended mission duration include:

- Vapor Solution Crystal Work

- Complete Solar Track—Entire Pass

- Full Earth Coverages Polar Orbit

The nonrecurring cost of developing the extended duration orbiter (EDO) capability has been roughly estimated at $100 million - $250 million for up to 20 day capability and in excess of $1 billion for more than 20 day capability. The recurring mission costs have not been analyzed, but would clearly be a function of mission duration. Our analysis to date indicates that it could be very difficult to justify the major expenditure of funds which may be necessary to extend the duration much beyond 20 days; we have not identified critical requirements for that time which could not be met more effectively by the Space Station.

We intend to allocate $1.5 million in FY 1984 to look further at extended duration and expanding the basic capabilities of the Shuttle.

CHART A

	FY 71	FY 72	FY 73	FY 74	FY 75	FY 76	TP	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83
Research & Development	78	100	199	475	799	1206	321	1343	1307	1269	1115	973	893	
Orbiter Procurement	—	—	—	—	—	—	—	67	33	270	588	737	835	664
Construct of Facilities	5	19	32	64	82	50	1	34	66	32	26	11	37	23
Research & Program Management	—	—	92	162	172	239	68	262	291	295	303	320	296	138

QUESTION M-67:

What is included in the fixed or overhead costs for the Shuttle operation? How will this change over the next five to ten years?

ANSWER M-67:

The manpower required to operate the facilities and equipment supporting the Space Shuttle's operations is customarily referred to as having a "fixed" and a "variable" component. By "fixed" we refer to the costs of providing and maintaining a given capability to fly a certain number of times per year (with some distribution within that rate for flying missions of varying complexity). That capability translates into the number of Orbiters required, ground launch processing facilities, mission control rooms, Shuttle training aircraft, hardware production facilities, etc. Adding additional facilities to provide greater capabilities usually results in some increase to the manpower needed to maintain and operate them. On the other hand, improvements to the inherent capabilities of the equipment, e.g., greater automation, may result in a decrease in the M&O manpower. We are in the process of increasing the production and flight rate capability of the STS up to a level of about 24 missions per year. As new facilities are being added, we are trying to improve the efficiency and effectiveness of the manpower required for their operation by providing better equipment and procedures, with the goal of keeping the manpower required for the "fixed" base at least constant — if not decreasing.

QUESTION M-68:

Are all fixed costs constant regardless of flight rate or fleet size? What about the needs for additional facilities for external tank and SRB production, hangars, Vertical Assembly Buildings, payload processing facilities, mobile launch platforms, etc? How does another orbiter affect the fixed cost base.

ANSWER M-68:

As the preceding answer indicates, "fixed costs" are not constant with regard to the actual flight rate or fleet size or number of facilities. The costs for operating and maintaining the Space Shuttle program are impacted by changes in capability, but we are concurrently attempting to improve the equipment and simplify the procedures so that we achieve an overall reduction in the cost of flying.

QUESTION M-69

How long would it take to build another orbiter if we started in FY 1985? If we had a stockpile of structural spares, how long would it take to assemble an orbiter?

ANSWER M-69

We currently estimate that it would take 4 to 5 years to fabricate an orbiter based on the availability of structural spares. Thus, a start in FY 1985 could result in an orbiter delivery in mid 1989.

QUESTION M-70

You testified that several problems were encountered during the full power level (FPL) certification activities which have "serious implications" for future operations costs. What are these implications and their associated cost impact?

ANSWER M-70:

The problems encountered during the full power level (FPL) certification tests were all associated with the durability and operating margins of the fuel and oxidizer high pressure pumps. The turbine section of the fuel pump and the bearings of the oxidizer pump require frequent and extensive maintenance when used for FPL operation. This is not to say the pumps are unusable at FPL; in fact, they have been certified for flight operation at that thrust level, but, rather the service life of the pump is much shorter than desired.

The cost impacts of the reduced service life arise from two sources. First, the more frequent and more extensive maintenance increases the labor hours. Second, the spare parts, complete pumps and pieceparts quantities increase significantly with reduced operating life. The Phase II Development program (described elsewhere in the response to item 29) is focused directly on the turbine/bearing problems. It is estimated that over the next decade the investment made in the Phase II development program will result in avoiding the expenditure of hundreds of millions of dollars which would be incurred to maintain and operate the current design pumps.

QUESTION M-71:

What are the estimated costs of developing Shuttle-derived launch vehicles (including the R&D program, additional facilities, and production capability, as well as the vehicles and fuels themselves) compared to purchase from a commercial source? Could comparable vehicles be commercially available?

ANSWER M-71:

Preliminary cost estimates are being reviewed for the SRB-X/Centaur configuration at this time. The Department of Defense has under consideration the procurement under commercial sponsorship of either a modified Titan 34D/Centaur or a modified Atlas/Centaur launch vehicle to provide equivalent Shuttle performance.

QUESTION M-72

The authorization required NASA to submit, by September 1983, the plan for maintenance of an ELV capability competitive with foreign vehicles and including appropriate recommendations for facilitating commercial ventures. Has NASA submitted this plan? If not, when will this be ready?

ANSWER M-72:

On January 13, 1983, NASA submitted a plan for maintaining a United States expendable launch vehicle capability to support the Space Transportation System.

QUESTION M-73:

In last year's authorization bill report we requested a report on a Shuttle Marketing Plan. How should such a marketing plan deal with the issue of competition with commercial ELV's?

ANSWER M-73:

Increased competition in the launch services area will help reduce transportation costs and increase the rate of space commercialization.

QUESTION M-74:

How will the use of the Westar and Palapa satellites affect insurance rates for future commercialization satellites launched by Shuttle?

ANSWER M-74:

Two types of Shuttle insurance are purchased by Shuttle customers: (1) third party liability which is required in the Launch Services Agreement in order to protect NASA and (2) launch success insurance (all risks insurance).

Prior to STS 41-B the cost of third party liability was approximately $75,000 to $100,000. Launch success insurance was available at a five percent premium rate (as compared to a 12 to 14 percent premium rate on Ariane).

We understand that all insurance premiums are going to increase; the differential between the rates charged Ariane and Shuttle customers is expected to be smaller in the future.

Mr. VOLKMER. Thank you very much, General Abrahamson.

We will begin with the gentleman from New Mexico.

Mr. LUJAN. Thank you very much, Mr. Chairman.

General, as you probably realize and probably know, one of the main discussions within the committee is the shuttle versus the space station, the moneys allocated to it.

General ABRAHAMSON. Yes, sir.

Mr. LUJAN. I am a supporter of both. As you would like to see the space program move along, so would I and so would all the members of this committee, and we look for the real way to move it on forward, within the constraints of the budget that we have.

Now, the operational side of NASA, just looking at the figures and in your statement of the $3.1 billion—$361 million is for research and development; the other is operational—so that that division has become primarily operational rather than research.

That bothers me, although I recognize that we have to have a good operational vehicle and system to be able to utilize the space station. But there seem to be, at least in my mind, so many things that we need to get straightened out as far as the shuttle is concerned—I am not talking about the management now; I am talking about the hardware——

General ABRAHAMSON. Thank you for that clarification, sir. [Laughter.]

Mr. LUJAN. My understanding is, for example, at landing, that the front wheel is kind of short and we have to look at that so that we don't get the big bang on it when it comes down. The hydraulic system, the wing structure in 103 and 104 are pretty weak, from what I understand, for taking off over at Vandenberg. The engine blew up when we wanted to get it to 109 percent.

Are we being foolish in moving ahead with the same vehicle that we have simply because we need a fifth one, and probably a sixth, and a seventh, eventually? Or should we say, hey, wait a minute?

Now is the time. We have these four ready to go, the spare parts, which we are working on. Is it time to pull back and say, let's take a look at a complete new design, even to the point that we don't have to use rockets to shoot it up or whatever? I have seen some designs of a smaller one taking off the back of a 747 in private industry.

General ABRAHAMSON. Yes, sir.

Mr. LUJAN. Are we at that point?

General ABRAHAMSON. Sir, I ask, and it is the kind of thing that we should continue to ask as we go through the program.

The Nation waited a decade, essentially, for the space shuttle, and in fact a lot of planning and many of the initiatives that are now beginning to come to fruition in space, and the revolution that I mentioned, are things that were kind of put on hold in that development period.

So what we are faced with, I believe, first of all, our management, but I think all of us, in terms of supporting a program, is a program that, first of all, is very successful, but it has some weak points that must be corrected, and you will see in our budget that the first priority of the agency has been to fully fund some of those weak points and correct them.

You mentioned the engine. One of the major runout items in the budget is over $900 million associated with improving the durability or the ability to run the engine and make sure that it is maintainable and it doesn't become a logistics burden at these higher rates of power, at 109 percent, out over a long period of time. So we are trying to upgrade the engine itself.

We have additional moneys that are included in the budget to invest in some of these weak points. For example, we have an additional $25 million that is planned for over a period of several years to upgrade the auxiliary power unit. We have a program that is certainly addressing the brakes. Our problem is we have not figured out exactly yet the best course of action. And, of course, we have a reserve in funding that is included to allow us to begin to tackle these things on a one-at-a-time basis.

I think that the Nation must go forward with the program we have and improve it as we go, but improve it at a level that we can afford, because the shuttle works well now, not perfectly. It is just like any airline that takes off. Any airline that takes off around this world, or airliner, has problems each time it takes off and each time it lands.

Mr. LUJAN. Oh, gosh, don't tell me that! [Laughter.]

General ABRAHAMSON. Fortunately, they are the minor problems. They are the ones that do not introduce safety problems, and that is where we think we are in the shuttle. But it is going to take a great deal of attention to insure that they stay in that area and that we now make it more logistically supportable.

So I believe that we embarked on a good program. There will be a time where the Nation should relook at transportation, the fundamental transportation, but I think that should be after we fill in other major elements of the space infrastructure so that we can keep exploration going, and obviously the space station is the next step, and then there will be other elements that are part of that infrastructure.

Mr. LUJAN. Well, I guess the point—I agree with you in that that first leg, which is the shuttle, may be completed already.

General ABRAHAMSON. It needs some improvement, but it is in work.

Mr. LUJAN. It needs some improvement. And since we do have four, and we are working on the spare parts portion of it, in order to buy time, I am sure, for that fifth orbiter but also for replacements, the amount of money that you are talking about for correcting those deficiencies doesn't seem like a lot of money to me. One of these days we could very well see, on landing, that front wheel collapse because of the problems associated with it, that it is too short, and those kinds of things are the things that kind of bother me.

We have talked, also, about an extended duration shuttle. Are we moving to the 25-day or whatever? Is that very difficult to accomplish by refurbishing our present fleet?

General ABRAHAMSON. We have been examining that——

Mr. LUJAN. How about 20?

General ABRAHAMSON. Yes, sir. and our preliminary studies indicate that it won't be too difficult to extend the duration of the orbiter, or perhaps one or two, maybe not each, out to a period on the

order of 15 days. Somewhere in that area. However, as you begin to go beyond that and go out to over 20, then we begin to find that there are major investments that are required.

Now, in order to understand that better, to really try to understand both the investment and the benefits associated with an extended duration orbiter, our plan is to invest about $1.5 million in an extended duration orbiter definition effort over this year, and we do think that that will give us a much better handle on that, and we do have to understand both sides, both the advantages of doing it as well as the engineering details of what it will cost and what is required to do it.

Mr. LUJAN. One final question: 1985 has no money for ELV's?

General ABRAHAMSON. That is correct.

Mr. LUJAN. Are we through with the ELV business and ready to say: "Private enterprise, it's your baby, go ahead"?

General ABRAHAMSON. There are still launches in 1985, but we have arrived at the point in the ELV program that for the last few launches, they are completely covered by reimbursable funding.

We have U.S. Government committed launches on the Delta program in 1984 and 1986, and we have Atlas launches out through 1986 as well, seven Atlas launches out through 1986,[1] and, of course, we have embarked on a program to turn those vehicles over to private enterprise and are actively negotiating with both Transpace Carriers for the Delta and General Dynamics for the Atlas Centaur.

And we have every expectation that they have a good chance of making that an effective program for themselves.

Mr. LUJAN. One final question that I have been holding back on and don't know whether to ask you or not to ask you, but I will ask, and if you want to plead the fifth or whatever, fine.

Did you ask, in your original budget submission, for a fifth orbiter?

General ABRAHAMSON. We have asked for a fifth orbiter at several times in the process, and I included it in our planning, but the agency did not ask for a fifth orbiter in the request that went over to the OMB.

Mr. LUJAN. Was it after negotiations that the request was not put in?

General ABRAHAMSON. No, I think that the real problem is the one that we have had each year, and that is that as we look ahead to the requirements and the buildup rate, while I think everybody feels that it would be a useful thing at some point, it is difficult to pin down a firm enough requirement that you are able to justify it.

Therefore, our approach has been the one that the President, I think, came to—a very effective compromise—and that was to build the structural spares; and when you combine that with our logistics program, we have extended the time in which you run out of production capability.

Now; it is getting tougher and tighter each year; there is just no question about it.

Mr. LUJAN. Is that just semantics?

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[1] General Abrahamson meant to say "* * * and we have Atlas launches out through 1987 as well, five Atlas launches out through 1988, and * * *."

General ABRAHAMSON. No, sir; it is not.

Mr. LUJAN. I really don't get the whole picture. Everybody says let's move ahead with the spares, because at some point we may want to build a fifth orbiter, and there we have the parts, then. What will be the spare parts then becomes the orbiter.

I am not sure if people are saying that as a backup position or just because NASA doesn't want to say we need a fifth one, but we will continue building the parts and then we will put it together at some later time. I can't quite get that straight, why that seems like a little game that is going on. I don't mean to say it in a bad way, but I can't quite get it straight.

General ABRAHAMSON. Sir, when you consider the ability to produce a fifth orbiter, I think you have to divide it into three parts. The first part is all of the components such as the valves and the pipes and the electronic components, computers, all of those kinds of things.

Our normal logistics program will allow us—and this has to be done with some difficulty, by the way—but it will allow us to have an ongoing capability either for production or repair, which means that at those various plants we do have some people, maybe not as many as one would like, but we do have people who are dedicated to the program and who are working that program. So at the component level, that is not a problem. Had we not embarked on the structural spares program, our major structural subcontractors would have gone out of business in fact about a year ago, people like Grumman for the wing, people like General Dynamics for the midfuselage. Those activities would have stopped. What this has allowed us to do is to keep those activities going so that we at least have the components of a fifth orbiter. We will not, of course, have the components of a sixth orbiter.

The last element in the production is the production line at Palmdale, where you finally take all of these parts, and instead of having them be a fifth orbiter, a lot of parts flying in close formation on the ground there, you really assemble it into a final orbiter, and with the delivery of the Atlantis at the end of this year, if there were not some modification programs, that production line then would be in difficulty. However, we are now examining a series of modification efforts and whether or not it makes good sense to do some of those at Palmdale versus some at Cape Kennedy in an effort to do two things: (1) to perform the modifications as cheaply as possible and as effectively as possible, and (2) to try to extend that manufacturing capability for another period of time. We call this a warm-line concept, and that is being actively worked now. So it is not merely a slogan, sir.

Mr. VOLKMER. If the gentleman would yield, I would like to just clarify one of the answers that you made, General Abrahamson. That is, on the $1.5 million on the extended duration orbiter for design and definition. You said: "this year." Is that this year—1984 fiscal year—or is that 1985 fiscal year?

General ABRAHAMSON. We are starting the studies in 1984 and expect that some of it will not be completed until into the 1985 period.

Mr. VOLKMER. All right. Thank you very much.

I will now recognize the gentleman from Kansas, the ranking minority member of the full committee, who I would like to say, I guess, is spending the time on the last set of authorization hearings on this subcommittee, after spending, I guess, over 20 years working on these programs; and I guess, as we look around the walls, he is one of the few that can say: "I was here then," and is still here working at it. I wish to welcome him again for all the efforts that he has done with this subcommittee in the past.

I now recognize the gentleman from Kansas for an outstanding job that he has done for space.

Mr. WINN. Thank you, Mr. Chairman, for those nice words.

Jim, on the parts program that Congressman Lujan mentioned, let me get down to try to help clarify in my own mind and maybe in the rest of the members of the committee.

OK, so of the four brakes on the last shuttle, we blew two of them, as I understand it from the newspapers. I haven't seen an updated report or anything. Is that basically it?

General ABRAHAMSON. Sir, we seem to have a continual problem on the right brake in particular, and it is the right outboard one that we just took out and are replacing completely and sending it back, yes.

Mr. WINN. OK. Now, where do we get the replacement brake? Where do we get it?

General ABRAHAMSON. We do have brakes that are part of our normal logistics program, but in this case I don't know if we had to take one off the—it is the Goodrich Corp.

Mr. WINN. I don't mean the company. I want to know if we are picking them off of something else, like the Air Force does once in a while.

General ABRAHAMSON. No; we are not taking them off any Air Force airplanes. I know that. [Laughter.]

This one came from our inventory of spares.

Mr. WINN. How many do we have? How many brakes can we burn out?

General ABRAHAMSON. We will have to get that for the record, sir.

[The information follows:]

We presently have in stock four spare brake assemblies with four more due in June. By June, we will also have sufficient rotors and stators in stock to rebuild twenty brake assemblies.

Due to a series of improvements made in the braking system, the degree of damage has decreased markedly on recent flights. We will continue to make improvements until the brake damage is eliminated. Pending final resolution of the remaining brake problem, our spares situation is satisfactory.

General ABRAHAMSON. It is not my intention to keep burning out one each time.

Mr. WINN. No, I understand that, but we have done it in the last two.

General ABRAHAMSON. Yes, sir, and until we find some——

Mr. WINN. And we might do it again.

General ABRAHAMSON. Yes, sir.

Mr. WINN. OK. Now, we don't have enough spare parts of every spare part necessary to put together a fifth orbiter, do we?

General ABRAHAMSON. We don't have them all delivered at this point.

Mr. WINN. Some of them are in the pipeline?

General ABRAHAMSON. We do have a spare parts program that, at an appropriate point, will be delivered. However, I would not like to give a false impression here. Our program is built around the number of parts that will allow us to maintain a 95-percent launch on time probability. That is kind of our calculation keypoint in our spares policy for the four orbiters.

Mr. WINN. For the four orbiters.

General ABRAHAMSON. So then if we suddenly started working on a fifth orbiter, and we, in order to maintain a production line, diverted some of the parts from that spares inventory into the fifth orbiter, then you can see we would have a shortfall not only for the four-orbiter fleet but also the fifth.

So what we would have to do, then, is continue to add on some additional spares at the tail end of those buys in order to make that up.

Mr. WINN. Yes, but that can amount to a startup, shutdown, startup, shutdown routine.

General ABRAHAMSON. We are examining that on a subcontractor-by-subcontractor basis.

Mr. WINN. All right. That is my next question. Have you done any figures on how many people might be laid off if we don't get a fifth orbiter?

General ABRAHAMSON. No, sir, I don't have that. That is a difficult one to establish because as we go into the logistics period, as opposed to the production period for the program, you have a natural reduction in the number of people on the program, because we are not building them as fast and you don't need as many spares, and in fact you want to have a warm production line concept.

So some of the people would leave the program anyhow, and then our job is to negotiate repair agreements which are efficient and have a minimum number of people but an effective capability that will be a sustaining one.

Mr. WINN. Yes, but there must be some type of schedule that you have worked out at this stage of the game based on the warm production line schedule as you call it, based on the parts that you have on hand, based on the parts that are in the pipeline.

General ABRAHAMSON. I just wanted to confirm. We tardily delivered a production report, and that production report has a particular type of graph in it that outlines for each of our major subcontractors where those crossover points and decision points are, and they vary.[1] And that is available to your staff.

Mr. WINN. I haven't seen that report. I would like to.

[The material referred to is in the appendix.]

General ABRAHAMSON. Yes, sir.

Mr. WINN. I would like to look into these possibilities. I am one that is in favor of both a fifth orbiter and a space station. I just can visualize that if we don't have the fifth orbiter now that we've got a lot of the parts available, as long as we've got the production

[1] Clarification offered by the witness: The report General Abrahamson referred to gives examples but does not cover each subcontractor.

lines going, that if we slow it down or shut it down or whatever we do, then to pick it back up in a year or two or three, whenever we decide we are going to need it again, we know darn well it is going to be more expensive.

General ABRAHAMSON. That is a true statement.

Mr. WINN. And there is only one set of people paying for that added expense, and that is the taxpayers.

General ABRAHAMSON. Yes, sir.

Mr. LUJAN. If the gentleman would yield, how much more? I keep hearing it is going to be more expensive, but how much more?

General ABRAHAMSON. We have wrestled with that, and it is a hard number to generate, and I apologize that I am not able to be more specific, because it does depend on the rate at which you decide, the delivery date that you pick for that orbiter, and the additional number of spares and how many people that you might have to add on.

There is no question that it will be more expensive, just none.[2]

Mr. LUJAN. Are we talking about $1 billion?

General ABRAHAMSON. Oh, no, sir. No, I think we are talking, you know, $200 million, $300 million, something like that, with any reasonable delivery times, 1989, 1990.

Mr. WINN. I am sure it would depend on when, how soon we could start the production lines back up, but it is going to cost more money.

General ABRAHAMSON. Yes, sir.

Mr. WINN. All you have to do is look at how much airplanes cost 5 years ago compared to how much they cost now, cars or anything else, whether it is a production line or not. The shuttle is hardly a production line. You cannot compare it with airplanes and cars, though we are getting to that stage.

A little different question: Are we going to be able to boost the two failed communications satellites into the right orbit? Are we going to be able to revive them or see that they survive or rescue them? I don't know how to word it, but it is a question that I get asked frequently, and I know that that probably was not on the drawing board anywhere, but it is not beyond the realm of being able to go up and replace those boosters, is it, sometime?

General ABRAHAMSON. One thing that we cannot do is, those satellites are in a much lower orbit than the TDRS was, and it is out of the question. They do not have the capability to kind of use the existing attitude control jets and the upper injection motor, which is still there and has not been fired, to get it up to orbit.

So that means that if we were to embark on such an attempt, we would have to bring it back down to the shuttle altitude and then either return it to Earth or in some way replace and put a new PAM type of solid rocket motor on it.

Mr. WINN. Yes; but we would have to recover it, then. We cannot send an astronaut out there untethered and have him replace it or do something to it?

General ABRAHAMSON. We don't know what all of those final answers are, and I will have to say it is one of those exciting pros-

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[2] Clarification offered by witness: Instead of "none", General Abrahamson intended to say "how much more."

pects that everybody likes to think about. The first step, however, is for somebody to ask us to do that and to be willing to put some money on it.

Mr. WINN. I suppose you would want some money out of Congress to do that?

General ABRAHAMSON. No, sir, not from you. We think that that should come from—or from you, from all of us—we think it should come from the commercial companies that would benefit.

Mr. WINN. Thank you very much. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you very much.

The Chair will now recognize the gentleman from Washington, Mr. Chandler.

Mr. CHANDLER. Thank you, Mr. Chairman.

General, the other day I had a discussion with a person involved in the space program, and he was saying:

> You know what we are really doing today is we are flying the Ford trimotor when we put a shuttle into space, and we ought to be thinking about the next level of technology.

I would like to direct a question to you about that. What are we doing in terms of the next level of technology? Should we be thinking instead of or in addition to the possibility of a fifth shuttle, of a new prototype of some kind? I also understand that there is some work going on at Langley with a new development, and if you could tell me how far along that is and address this particular question, I would appreciate it.

General ABRAHAMSON. There are really two types of new technology that are applicable, sir. One is the kind of new technology that you might use to upgrade the present system. We do have some very small amounts of money being looked at in an entirely new avionic architecture that could work either for the shuttle or for a space station or other space applications. That is under way. It is a very small investment and it is very preliminary, but it is an attempt to project out into the 1990 timeframe and see what one would need, particularly as some of the avionics in the shuttle become obsolete and as we need very highly reliable avionics for a space station. So there is some very limited work going on of that kind.

However, I think you are referring to a whole new vehicle concept, that type of thing.

Mr. CHANDLER. Yes; the kind of thing that might be launched from an airplane or a runway type of launch.

General ABRAHAMSON. Yes. There is work within NASA looking at kind of a space version of the old X vehicles. NASA had the X-15 which, of course, really blazed an entire new area in aerodynamic research. This would be a vehicle that you would carry up in the shuttle into space and then drop it down, and it would not be, like the shuttle, an operational airplane, but it would be a space plane, and it would be a research vehicle.

Now, that kind of activity is at least complementary to some interest on the part of the Air Force which is also being studied for a more operational version of such a thing, and there is communication going back and forth about those things. But that is very, very exploratory at this point. They are just advanced studies.

Mr. CHANDLER. Is there work being done on the type of spacecraft that I mentioned that would be launched from perhaps a runway or flown from an aircraft, not launched from the shuttle itself?

General ABRAHAMSON. The Air Force interest, which is coming out of the laboratories out at Wright-Patterson, and they are very, very small study contracts, is for a vehicle, a much smaller one than the shuttle, which could be launched either from a runway or from the back of a 747 or a high-speed airplane of some kind, and then go into orbit.

Mr. CHANDLER. Are we moving quickly enough?

General ABRAHAMSON. That is, frankly, always hard to judge; sir. I think it is important that we are undertaking those kinds of studies now. The Russians are doing some similar work, although we have seen at least something that is related in their small space plane that has come down. We don't know how that might be applied.

I am just frankly not in a position to say. I think the important area that we should emphasize now is not the new vehicles so much as making use of the great advantages that the United States has now in our avionic technology. I think the greatest strides for all of space applications in the next decade or two will be in applying the tremendous advances we have made in the computer industry to modernized versions of avionics for not only the shuttle but the space station and, frankly, for our various payloads. That is my own judgment.

Mr. CHANDLER. Well, that is a good answer to the question, and I appreciate it.

You also mentioned the shortage of spare engines and pumps. Is there money in your request to take care of this?

General ABRAHAMSON. Yes, sir. It is over $900 million over the runout period of the budget, and how much this year? We will get that figure. It is money that is divided into two parts. The purchase of additional engines for spares, four additional engines, is being undertaken; additional pumps of the present design; and then some improvements that are required to make the present design a better design and a more durable design.

Mr. CHANDLER. If I can just ask one final question, this is a close-to-home one concerning the inertial upper stage, and I have some questions regarding that and the other upper stage units that I will submit in writing, but I would just like to know at this point, what is your assessment of the progress being made toward correcting whatever problems there are in getting another launch under way?

General ABRAHAMSON. I think that the contractor, NASA, and Air Force teams that are working it are working it very effectively, but I will have to say that I am personally discouraged.

We have not found an easy way around what are some fairly fundamental problems in the IUS motor design.

Mr. CHANDLER. Thank you, Mr. Chairman.

Mr. VOLKMER. The Chair will now recognize the gentleman from California, Mr. Lowery.

Mr. LOWERY. Thank you, Mr. Chairman.

General, what is the current status to commercialize space, specifically through the ELV's? Let me be more specific with my ques-

tion if I might. How have the decisions of NASA and within the administration on commercialization of ELV's interacted on a decision on a fifth orbiter, if they have? Do you all assess that there is a sufficient commercial ELV market out there without some type of Government support or subsidy, if you will, and are there any intentions to assist that commercialization industry either through some type of NASA support—purchasing of ELV launches, providing technical assistance, or possibly access to launching or tracking facilities?

General ABRAHAMSON. First of all, the status of the activity is, we went out with requests for proposals late in the summer, and we did get proposals back, and we have essentially selected the commercial entrepreneurs that we want to work with, and on the Delta, it is Transpace Carriers, and we are presently negotiating with them a final agreement for that activity.

NASA has six Government launches that are scheduled. We have offered to them the ability to take over a portion of those, the last two; that is, if they sell enough that is commercially viable for them—that is three—in both of our judgments to do that.

So we are moving out very effectively, we think, with that organization.

Mr. LOWERY. How many organizations responded to your RFP and how many have you selected?

General ABRAHAMSON. On the Delta, we only had one organization that wanted to take them over. We had another organization that wanted to just get some of the equipment, and we elected to go in favor of the organization that wished to take them over.

On the Centaur—and this is the Atlas Centaur—[GD], General Dynamics, was the only proposer in that case, and we are also in negotiations with them. They were not interested in the near term in taking over the seven additional launches that are Government-contracted-for launches at this time. However, once they complete the negotiation and begin with their marketing effort, they indicated they may wish to come back and revisit that question.

Now, we have not provided any substantial intent for subsidy here, although we do feel that we have a reasonable price where there is excess equipment—and that is only in the case of the Delta—in terms of the rocket motors themselves.

However, we are assisting them by making available the facilities that we presently launch from and presently use in a very attractive way, we think, and, of course, that requires some cooperation between the Air Force and NASA in negotiating that, and those negotiations are under way as well.

On a cost basis, we are trying to provide these facilities on essentially an additive kind of cost basis which is very similar to the way the shuttle program is costing to customers.

Mr. LOWERY. Are you looking at anything beyond what you have described in terms of——

General ABRAHAMSON. Well, there are other—these are the turnover of our existing systems. There are other people out there, of course. The Conestoga organization is marching on and hopes to launch from Louisiana at some point. There is formerly the Starstruck organization, now called Dolphin, I guess, who were going

off the Pacific coast, and if they would not have had a problem, they probably would have launched by now.

I think that those are pioneering entrepreneurs, and they didn't want any help from us. They just wanted to go ahead on their own.

Mr. LOWERY. You see a market, then?

General ABRAHAMSON. Pardon me, sir?

Mr. LOWERY. You do definitely see a market?

General ABRAHAMSON. I see some market. I see that—my own judgment is that there will be certain people that will be able to offer services that are complementary or different from the shuttle, as I have indicated in the past, particularly people who may offer more routine service to orbits that we don't normally go to or payload size, things that will be of advantage. My own judgment is that is the best business area, but there are others who would like to work for the same communications-size satellites.

Mr. LOWERY. To follow up on my question, how about the ELV's as they relate to the fifth orbiter?

General ABRAHAMSON. We in NASA—and I am not aware of anywhere else in the administration that people have just definitely said that because of the ELV activity we don't need a fifth orbiter. I don't think that kind of analysis has been done.

I think the reason that that kind of analysis is not really possible at this point is because it is murky when and where all of this market is going to develop. Many of us are real optimists, and we think that America's future is in space, and it is going to be big, and obviously some of these entrepreneurs feel the same way; otherwise, they wouldn't be making that investment. But it is very hard to judge specifically.

Mr. LOWERY. But there has not been a decision on postponing the fifth orbiter or delaying it because ELV is going to take up the slack over the short term?

General ABRAHAMSON. Certainly not within NASA, and as I indicated, I am not aware of it anywhere else.

Mr. LOWERY. What about the NASA Advisory Council recommendation that NASA retain the ELV capability?

General ABRAHAMSON. I think that is a considered recommendation, and we do have in the near term at least two spare Deltas that we are holding in our capability. But there comes a point in time where I think that it will be much more effective to have that transition to the private entrepreneurs, and I think that is consistent with the President's policy of transfer.

Mr. LOWERY. Where are the problems with transitioning over to DOT as the lead agency?

General ABRAHAMSON. I am sorry?

Mr. LOWERY. The problems with transitioning to DOT as the lead agency.

General ABRAHAMSON. Well, the DOT lead agency is intended, of course, to provide a bureaucratic focus so that it will be easy for these entrepreneurs to move ahead. We don't see any problem with that. I think that that allows NASA to continue to provide technical assistance and support.

Mr. LOWERY. A final question on the recent failure. As close as I can pinpoint from the new accounts, it seemed to be in the PAM. Have you been working with the contractor in trying to resolve it?

General ABRAHAMSON. Yes, sir.

Mr. LOWERY. Also, is there any thought of a rescue operation of Westar or Palapa using the shuttle?

General ABRAHAMSON. We, very early in the process, had a request from the McDonnell Douglas Corp. to provide assistance, and we were happy to do that. Our future is bound up just like their's in that inertial program. So we are providing assistance at their request, and we will provide as many experts of the type that we all may need. We don't have results from that investigation yet. It is really a little too early to begin to reasonably expect those results.

By the way, this is a serious problem. It is a serious problem not merely for the shuttle, because there are other vehicles. For example, the Ariane that is now waiting to go, the spacecraft, the Intelsat spacecraft that goes on that, has an upper stage which is the injection motor to put it right into its final geosynchronous orbit, which is of the same nozzle design as the one that failed in ours.

There is the motor which supports a military launch of the global positioning system, which also has two motors with the same design. So it is a national and international problem that we need to solve quickly, and we are working to do that.

Mr. LOWERY. What about a rescue operation? Is that at all feasible?

General ABRAHAMSON. It is possible. It is an exciting idea, and a lot of people, of course, have ideas about it. While there are some discussions going on, we really think that a formal activity requires the request of the people who own the satellites.

Mr. LOWERY. Thank you, General.

Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you.

The Chair now recognizes the gentleman from Florida, Mr. Nelson.

Mr. NELSON. Thank you, Mr. Chairman.

Good afternoon, General. You are doing a great job. We appreciate it, and I am glad for the opportunity that this little country lawyer could ask such a fashionable, good taste, high-flying general who is an expert space planner about a number of things affecting the country.

General ABRAHAMSON. Mr. Nelson, since you provided such fine weather for our landing, we are delighted to have you ask questions, but I think I am in trouble. [Laughter.]

Mr. NELSON. No, I am just thankful that the sun broke through the clouds right before landing occurred, because I always get it, particularly from Dick Smith, when the weather is bad.

You know, every transportation system that we have ever had, be it on ground or be it in the air, and now—as we plan for the transportation system of the future—in space, it seems like most planners—and you are the planner— provide for some kind of backup. I cannot imagine an airline providing that it needed x number of airplanes and just ordering that x number of airplanes without realizing that some time it is going to have to have some backup capability for maintenance or, from time to time, that some kind of maintenance or transfiguration might have to occur that was beyond our expectations.

Now, with that as a predicate, let me ask you, say, if in the late eighties we in fact did have down time of, say, 18 months on one of a fleet of four orbiters, from what we project on a manifest, aren't we talking about the loss of about 15 payloads, 8 flights, and the delay of scores additionally?

General ABRAHAMSON. You are on the right order of magnitude. We do expect that the orbiters will be able to maintain, on a routine basis, 6 or more flights per year, and of course that is our planning number as we go out to 1988 and 1989; and that we could surge for a short time higher than that, but for a long downtime of 18 months, as you have indicated, it would be on the order of 8 to 9 payloads. That would be the impact, yes, sir.

Mr. NELSON. Well, with this being the only way that we can get into space on a United States vehicle on some of our payloads that would not be able to be carried on some of the expendables, commercialized, then would you explain to this little country lawyer what is the reasoning of why we are not making the commitment that we want to have that backup capability there as we look to our future space transportation needs?

General ABRAHAMSON. Frankly, I think it is a question of kind of incrementally going into the backup. At some point in time, I am convinced the Nation will need additional space launch capability, and I think the question is, when is our crystal ball good enough so that we can see that we really do need to start it now, and obviously, as Mr. Lujan has indicated, and what is a reasonable price.

But the backup comes in many ways. It is not only in a fifth orbiter. It is in sufficient logistics capability so that we can avoid an 18-month downtime, and that is always difficult because there are scenarios that you could predicate that might put you in that capability. But our job is to make it one that that probability is absolutely minimized. Now, the backups then fall into three categories: logistics capability; very well, potentially, a fifth orbiter at some point in time when it is properly justified; and, frankly, looking into additional lift devices at some point. In the budget this time we do have a $5 million request for planning for a shuttle-derived launch vehicle family, which is——

Mr. NELSON. Not available to us by the end of the eighties.

General ABRAHAMSON. No, sir; that would be much later than that, but we are trying to look ahead, and I am trying to say that I hope we are being reasonable planners in that regard.

Mr. NELSON. Well, Mr. Chairman, I thank you for the opportunity, before I have to dash off to another meeting. I would request that I might be able to submit in writing—I would like some thoughts on an extended duration orbiter and that vis-a-vis the space station, et cetera.

[The information follows:]

We have, for a number of years, looked at the potential need for an extended duration orbiter and have identified three areas where a mission duration capability of 14 days could be useful: (1) Vapor Solution Crystal Work; (2) Complete Solar Track—Entire Pass, and (3) Full Earth Coverage, Polar Orbit.

Our analysis to date indicates that it would be very difficult to justify the major expenditure of funds, control and avionics changes which would be necessary to extend the duration beyond 20 days with no identified critical requirements for that time which could not be met more effectively by the Space Station.

Therefore, we intend to allocate $1.5 million to look further at extended duration and expanding the basic capabilities of the Shuttle. This will include how we can bring the cost down; the most effective way to implement potential changes; and studying the options to systematically trade off each of the user community needs, especially on the scientific side.

Mr. NELSON. Let me say that I know that the general and NASA and his boss, Mr. Beggs, have all kinds of financial and political constraints on them with regard to this, and as was the case with the Congress last year in helping you out of your dilemma, we might be able to help you along this year, I hope, but it is getting more and more difficult, because the later and later that we delay, the more and more costly it ultimately becomes whenever we do have to crank it up into full production on the fifth orbiter.

Thank you, Mr. Chairman. I appreciate it.

Mr. VOLKMER. Thank you.

The Chair will now recognize the gentleman from Virginia, Mr. Bateman.

Mr. BATEMAN. Thank you, Mr. Chairman.

General, it is good to have you back before the committee.

I wanted, if I may, to follow up very briefly on questions asked by the gentleman from California, Mr. Lowery, about the failure of the Westar and the Indonesian satellite.

Am I correct that the PAM or whatever you called it that failed on those two satellites was two of a lot of five?

General ABRAHAMSON. It has been reported that way, and that is an accurate number in some respects. The way these motors are assembled, certain operations are done in batches of various sizes. For example, when they pour the motors and pour the solid propellant inside, I believe that they are able to pour the motors and then put them in and cure them properly in batches of about three at a time. I am not absolutely sure of that number, but I think it is on that magnitude.

Other operations, they may be able to lay them up, the nozzles, in batches of five, so that it is an oversimplification to say that it is clearly a batch of five. However, the two that failed, the key elements, the exit nozzles on those, they were made in sequence in a production line operation, and when you see that kind of thing happen, you look very closely and say: "What is different from the many successes that we had previous to that?" And we did have 18 successful civilian launchings and 2 successful military launchings of those upper stages.

Mr. BATEMAN. So it is certainly unclear at this point that there is a high risk of others in the series which are in part a batch failing because these two failed.

General ABRAHAMSON. There is a real potential of that, and until we understand the failure more adequately, I think you must assume that there is potentially that.

Mr. BATEMAN. But there is no determination that is satisfactory to you or to NASA as to precisely what the failure was and whether, indeed, it is an indication of a high risk of failure on the part of the remainder?

General ABRAHAMSON. We have a thesis about the failure, what happened, but not why. What we think is the most likely failure scenario is that there is an exit cone made of a two-dimensional

carbon-carbon material which is a composite and which has all of the art of laying up these composite materials, and there was a failure approximately 3 years ago where a piece of that broke off. When it breaks off, that allows the hot gases to expand into finally a titanium support structure, and the failure that occurred 3 years ago was that the whole nozzle end kind of came out. That means a big hole in the motor, and when that happens you lose pressure, and it goes out.

So that is a suspect area, but that does not explain why.

Mr. BATEMAN. Now, Mr. Chairman, if I might, I would like to turn for a moment to a question much on our minds today apparently of the, quote, fifth orbiter.

From listening to the testimony, I wonder if it is perhaps not more accurate to say we have now 4-and-a-fraction orbiters, and if we keep adding to the parts, we are going to end up, say, if we have 4½ now, we will have 4¾, and if we keep on, maybe we will then have 5, if then assembled, or maybe 5¼, if the requisite ones are assembled.

Is there any validity to that analysis?

General ABRAHAMSON. That is a very good analysis, sir.

Mr. BATEMAN. I would take it that as we go forward with the acquisition of additional spares, maintaining the production capability, that what is being obtained at any point in time as a spare is selected on the basis of that which is most likely to need to be replaced on one of the existing four orbiters.

Is anyone doing any analysis as to how far we are toward additional spares that there is a higher probability or predictability of needing? Does that question come through to you?

General ABRAHAMSON. Yes, you are correct, sir. We do decide on the size of the spares order through a very complex thing we call the provisioning process. The first criterion is, do we need that spare?

However, we also examine, is that production line beginning to run out? And in some cases we modify our thinking just a little bit or we try to be prudent planners and look ahead and say: "Well, is it a worthwhile buy to buy two or three more?" Of course, that is easy when the things are inexpensive, and it is harder when they are very expensive. So the process is, first of all, do we need the spare? And we do consider what the production line capability is.

Mr. BATEMAN. If I have a minute more, Mr. Chairman, in terms of your budget request for fiscal year 1985, does it come—insofar as keeping a production capability alive for a fifth orbiter—does it come with a set of recommendations as to specifically what spares, what components it is contemplated, would be procured if those appropriations are approved?

General ABRAHAMSON. Yes, sir, it does.

Mr. BATEMAN. In other words, that is not something to be done; that is a part of the budgetary submission.

General ABRAHAMSON. That is part of the budgetary submission. As we get into the out years, we are kind of making broader estimates, but in the budget year, it is there.

I would not want to leave a false impression again, however, that there are not some near-term specific components that we consider to be problem areas that would cost more to reinitiate. That is the

case. Our total spares this year, just to show, is some $624 million. It is a very major investment in spares. But that does include engines, which are a pretty big chunk. But it is a large amount for orbiters, and of course that is what your attention is directed to.

Mr. BATEMAN. Thank you, General Abrahamson.

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. I would just like to continue on with that just for a moment. As I read the figures I have been provided on spares, between the period of 1983 through 1989, we have $2.4 billion for spares total. Is that correct?

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. The gentleman from Pennsylvania.

Mr. WALKER. Thank you, Mr. Chairman.

You are down to the lower-tier questions here now, general. You should consider it a sign of popularity that the minority was here in such numbers for your testimony that they forced some of us off the podium. [Laughter.]

Mr. VOLKMER. You can move back up now. [Laughter.]

Mr. WALKER. That is all right. Once here, I will stay seated. Thank you, Mr. Chairman.

Has any thought been given at all to trying to solicit some international cooperation for building the fifth orbiter? In other words, getting some of our international partners such as the Japanese and the Europeans to help finance the fifth orbiter?

General ABRAHAMSON. No, sir, and there is a reason for that. We are, of course, very anxious to do things with our foreign partners. However, usually that is a kind of quid pro quo arrangement, and in that arrangement they are interested in several things, in getting some technology and doing some investment, and since the orbiter is an established production line in the United States, it is just not a good candidate for that.

Now, there are a couple of exceptional areas, for example. If we increased our orbiter fleet dramatically, one might say, Well, we ought to look again and see if we need another Canada arm, that kind of question, but that is just a unique opportunity that was already founded in international cooperative effort.

Mr. WALKER. Well, the analogy was used earlier about the Ford trimotor or the DC-1 or whatever you want to call it. The fact is, though, that a lot of those countries are buying U.S. airplanes right now to fly payloads in, and a number of them obviously are going to have payloads for the future that they want to fly of their own. It seems to me that they might want to buy a product being built in the United States that offers them some unique capabilities that they don't now possess, if in fact we approach them with the idea that they are going to have a payload capacity that they wouldn't otherwise have if there is a fifth orbiter in place.

I am just wondering whether or not it is at least worth exploring if, in the context of our budget constraints we cannot fully commit ourselves to a fifth orbiter, whether or not we ought to find some other way of reaching out to get the capacity using international cooperation.

Well, that is something we will pursue here. It is a policy decision probably more than it is a decision for you, but on the other

hand, it would be helpful to have some data from some people that might have done some negotiating on that.

General ABRAHAMSON. Well, I have done a lot of negotiating in that area, sir, not only on this program but also in previous programs. It is an area, I think, worth examining, and there is an additional area that we are examining, and that is, is there any activity within just our customer base, the people who eventually will want that service for putting up various satellites, that makes sense, economic sense, on all sides?

So we are trying not to be too close-minded, and I appreciate your suggestion.

Mr. WALKER. Thank you.

To go on with the point you just made, I recently saw a document, a NASA document, that was talking about a marketing strategy for the shuttle, and I was somewhat disturbed by some elements of it which appeared to me to be, in effect, an attempt to almost inspire some unfair competition in private industry. I mean that is my interpretation, not the interpretation of the document. But what I am saying is, it appeared to me as though there was a marketing strategy being put in place that would use basically Government subsidization as a means to freeze out private competition.

Am I misreading the document? Is there a problem here that I perceive rather than a real problem in that regard?

General ABRAHAMSON. Sir, I am really—could you be just a little more specific so I can get on——

Mr. WALKER. Well, all it is, it is an internal document from NASA which goes into some detail as to future marketing strategies for shuttle, and there were some portions of it which struck me as being virtually an attempt for NASA to go far more into the marketing business and do so in direct competition with private industry efforts.

General ABRAHAMSON. Oh, I see. Now I understand what you are saying.

We are interested, and we are developing planning, although it does not have yet a final agency approval, for support for our efforts to go and find and get more customers. There has been a great deal of attention, as we are working that out, on the question of is that unfair competition for external marketers. I would like to point out that there have been people on the outside who have come to us and proposed different concepts for marketing, and those people have ranged from people who are advertising experts and who want to come and help us advertise—to which my answer is, "This is ridiculous." Frankly, the shuttle is the most advertised kind of thing in the world at this point. We don't need Madison Avenue sellers.

In the end, we need, in my judgment, a partnership between some of industry's capabilities and the credibility associated with NASA, and I assure you that what in the end is sold, and I personally have been part of the teams that go out to sell to someone a ride in a shuttle, and it isn't taking people to lunch, and it isn't somebody with an effective marketing approach in the end that does the job.

In the end, what somebody signs up for is, they say, We want the reliability and the capability of NASA. It is not shuttle versus Ariane, either, by the way. Let me give you just one example of that. In the middle of our terrible troubles on this last launch, where we were working very hard to try to understand what happened to the first Westar-6 satellite and to indicate what it is that it was best to do, we had the strong partnership between the Air Force and NORAD providing us information, and the NASA team that was providing calculations and efforts.

Now, the next customer up on the shuttle that has to use a PAM is Telesat Canada in June, and they had a representative here, and after we had the second failure, that representative came over and said:

> You know, I would no more consider going on the Ariane after this demonstration than anything at all, because of the resources and the support that the United States can pull in and put on this program.

It is my judgment that somebody out to try to market the shuttle for the shuttle does not offer that credibility. NASA does.

Mr. WALKER. I think you make a valid point. I guess, to some extent, what I gathered from what I saw—what I am told is that this is a draft RFP, is the thing I was referring to. What I guess I gathered to some extent was that NASA wanted to market those things which they were capable of doing and which they knew they had capacities for doing, and it did not appear to me as though there was anything in there that was going to lend itself to marketing toward innovative pursuits within private industry.

So I got the feeling that, to some extent, we are willing to stand back and allow a position in Government—one reason why you have all these capabilities is because Government has provided those capabilities in years past, so you were going to go out and market those capabilities with some degree of Government subsidization, and yet almost it appeared to me to freeze out some of the innovative things that are coming in from the private sector, and that is my concern.

General ABRAHAMSON. Well, that is a valid concern, and that is why we are reworking the earlier versions of that, by the way.

Mr. WALKER. I guess that satisfies me, then.

General ABRAHAMSON. That is valid.

Mr. WALKER. I may have seen an early one, and that is where the concern came from.

One other question, and it follows up the question Mr. Chandler asked.

General ABRAHAMSON. In fact, I am not pleased, because all too often we have some difficulties in the press in terms of early working things are then—because NASA is an open agency—are published as what our final intent is, and that is not the case. You know, we work those things pretty hard.

Mr. WALKER. I appreciate that.

One follow-up to the question Mr. Chandler asked in terms of new generations of space capabilities: My understanding is, in talking to some of the folks in NASA who are among some of your forward thinkers, that we do have the capacity probably, the technical capacity, now to begin building a chemical rocket that would dras-

tically reduce the per-pound cost of going into space. How far down the road are we toward actually trying to develop such a capacity?

General ABRAHAMSON. When you say chemical rocket, perhaps if you can be a little more specific about—are you thinking about some new propulsive——

Mr. WALKER. I am talking about, primarily, yes, a new propulsion system more than anything else. It was represented to me as something that could drastically reduce the cost. It is essentially, again, taking the DC-1 analogy, taking the shuttle and making it into a DC-3.

General ABRAHAMSON. Well, there are several different kinds of things, and these are all in the very advanced study phase, and perhaps the one you are referring to is some higher energy state propulsive chemicals that we haven't used before. We have used just kind of the normal energy state for hydrogen, oxygen, and those kinds of things.

I think they are quite a ways away, sir. I think they are more than a decade away. In the near term, however, there are important efficiencies that we can get by structuring our vehicles and our infrastructure in a very effective way. But I think some of those advanced ideas are a decade away.

Mr. WALKER. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you.

The Chair will now recognize the gentleman from California, Mr. Dymally.

Mr. DYMALLY. Thank you very much, Mr. Chairman.

General, you may have been asked this question before, but it is of some district relevance, so I need to repeat it. It is the question about the fifth orbiter.

First let me preface my question with a little concern. I find it rather strange that you would be attempting to go into space, which is a very costly venture, but at the same time neglecting the fifth orbiter, given the fact that we are tooled up in terms of everything except money, and I know last year your request was turned down by OMB. I suspect this year you sort of played in cool—forgive the vernacular—and didn't try to ruffle any feathers at OMB.

But I am concerned because it impacts very heavily on the district I represent in terms of employment, which is always a legitimate concern, and of course southern California at large.

Why is NASA not pushing for the completion of this fifth orbiter?

General ABRAHAMSON. I think we of course are interested in it; there is just no question. But the question is one of priorities and timing. For example, the priorities in our overall budget request this time were for solving some of the problems that we have talked about in previous questions here; for example, upgrading our engines, having some money to attend to improving the APU, buying sufficient spares. You just have to set up a set of priorities, and of course then there has to be an overall affordability decision that is made.

Within the fleet, we think that we have set up those priorities in a reasonable way, that it is more important to have the spares and the engines for four orbiters at this point than it is to have five orbiters and have two of them without engines.

So while we are concerned with that balance, that has been the basis of our judgment.

Mr. DYMALLY. Why can't we go for the whole banana? [Laughter.]

General ABRAHAMSON. Well, that is an overall affordability question, of course, and that is a difficult one.

Mr. DYMALLY. Well, you are going to be asking us, obviously, to authorize large sums of money for the space program.

General ABRAHAMSON. Yes, sir.

Mr. DYMALLY. And yet this last piece of that program is of great concern to a number of us, especially the California delegation.

I would like to think that NASA would rethink its strategy on this and impress upon OMB the importance of completing this fifth stage. I think it is of importance to the whole space program, to the economy, and rather than abandon what we have already put into place.

General ABRAHAMSON. Yes, sir.

Mr. DYMALLY. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you, the gentleman from California.

I have several questions. One of them has to do with what the gentleman from California just discussed, and other members have discussed. As I understand it, *Columbia* will go in next year, in January, for refurbishing, which will take about 6 months.

General ABRAHAMSON. Yes, sir. It is already in a refurbishment process now, but it will fly in the fall, in August, so this is just another in the process of—*Columbia* does require upgrading, of course, because it was the first vehicle and the experimental vehicle, and we are trying to do that in a way that doesn't impact our overall flight schedule.

We did look at options, of course, to do it all very, very efficiently, and finally decided that an airplane that doesn't fly is going to get us all in trouble, and in the Air Force I can assure you that the hangar queens are very difficult to get back, so we are modding it a little bit, then flying it, and then we will do some final mods after the *Atlantis* is completed.

Mr. VOLKMER. Do you anticipate any further modifications, say, in 3 or 4 years, not only for the *Columbia* but the *Challenger* and *Discovery?*

General ABRAHAMSON. Yes, sir. I think that there will be some minor modifications, not any of the magnitude associated with the *Columbia*, but I do believe there will be some.

Mr. VOLKMER. You don't anticipate any long-time down time for any of them, then?

General ABRAHAMSON. No, sir.

Mr. VOLKMER. In the event that something did occur and we had such things as, say, one of the orbiters down for 12 or 16 or 18 months, how would that impact, let's say, in 1988 or 1987 on our flight rate?

General ABRAHAMSON. In terms of our ability to handle in a steady operation, it would be, I am sure, the loss of eight or nine flights, and it would be a difficult thing to work around, if an orbiter were down for that long period of time. I believe that our objective must be to find ways to avoid having it stay down that long, of course.

Mr. VOLKMER. Let's assume and hope that the STS never incurs an accident that results in loss of an orbiter, but do we have to assume that there will be some attrition in the use of the orbiter fleet?

General ABRAHAMSON. I think the answer is yes. I am sure that there will be—our job, of course, is to avoid any kind of a disaster, and even a minor accident, but at some point there will be things that will happen that will damage minor parts of the structure, and that is why, of course, having flaps there that are available, having —for example, right now we are taking off the OMS pod. This is the large bumps on the back of the orbiter, of course, that have our orbital maneuvering system engines in them.

What we did is, we had an ice damage occurrence on the left-hand OMS pod, and, fortunately, we have the OMS pod available from the *Discovery* there, and we are taking off the OMS pod on the *Challenger* and putting on the OMS pod from the *Discovery.* That allows us time enough to take that OMS pod back and fix up this damaged area, which will take several months to repair, and without impacting our 41-C flight.

Those kinds of things are what being a fleet manager is about, and it is a difficult problem. But that will happen, I think.

Mr. VOLKMER. And is that built into the projection in the late eighties of 24 flights a year and still being able to do those things?

General ABRAHAMSON. Yes, sir, routine maintenance is, sir, and extended downtime is not.

Mr. VOLKMER. Now, on the possibility of an extended duration orbiter—and we have had some discussions here already as to the cost—I have heard of some estimates that if you want to go to a modification on one of them to do 20 or 21 days, it would run somewhere around $75 million. Would you say that is accurate or inaccurate?

General ABRAHAMSON. Well, there have been several preliminary estimates that indicate that if you get above 20 days or so, yes, indeed, you begin to get modifications on that order of magnitude that fall in that area.

That is why we are investing the $1.5 million now to begin to look very carefully at those engineering activities, so that we can come back with a much more accurate number. We believe that there will be a breakpoint at around 15, 16 days, somewhere in there, where it will be a much more reasonable and affordable number and where it may really make sense, given the benefits that could accrue, if one or more of the orbiters could extend that long.

Mr. VOLKMER. If even one orbiter is used again during the late eighties, in that timeframe, for an extended orbit period, will that not impact on your 24—if you have 4, will that not impact on your 24-a-year flights?

General ABRAHAMSON. It will impact. However, we think that if it is extending an average mission from 6, 7, or 8 days up to 14 days or 2 weeks, while undoubtedly there will be an impact, it will be not a significant one. I think the most significant operational impact, if we did have an orbiter of that kind, would be that we would have to schedule it very carefully for those particular missions, and that means that we would not have all the flexibility

one would like as you go through a sequence of missions. If you are going to use that one in May, you cannot be using it in April just to send up on a short flight.

Mr. VOLKMER. The gentleman from New Mexico commented very briefly, and I would like to have some more specific answers about the wing structures for 103 and 104, as to the question of whether there is sufficient strength for operation from Vandenberg for some of the DOD missions. Can you comment on that?

General ABRAHAMSON. Yes, sir. It goes back to the problem that the shuttle, of course, is a pioneering development, and when the original shuttle work was done in a wind tunnel, there were some things associated with the aft end of the shuttle that made the wind tunnel work in error. Of course, in order to try to get the maximum performance of the shuttle, there has been an active weight reduction program over several years, primarily starting from 1976, and the last orbiters, 103 and 104, have the benefits of that weight reduction program, meaning a much lighter wing.

Now, unfortunately, because there was an error in that, a very understandable error, by the way, because of the pioneering aspect of the program, we do have a problem. So what we have done—I think we have a very adequate fix in the near term in that we have put some cross-straps or just some very simple modifications on. It cost us about 300 or 400 pounds in weight and not a great deal in terms of dollars. That will allow us to operate reasonably from Vandenberg and from KSC and operate effectively.

Mr. VOLKMER. Those cross-straps are within the wing?

General ABRAHAMSON. Yes, we just take off the leading edge of the wing and then we just put on these cross-straps, and the leading edges are special parts that come off easily and go back on easily. So we don't consider that a major problem. We do, however, want to get the last little bit of performance that we can; and therefore, we are continuing to look at ways to get different angles of attack on, and that is not solved yet. So if we can improve that, we can get additional performance for Vandenberg and for other places.

There are other ways of getting additional performance as well that we are looking at, too. So we are not in a situation that even though the wings are weaker on 103 and 104, that they cannot meet their mission. We have upgraded them so that they can. But we would like to get a more elegant solution so that we can get a little bit more performance out of it.

Mr. VOLKMER. Do you anticipate that you will be able to resolve it and obtain the additional performance?

General ABRAHAMSON. There are some subtleties in this, and frankly, I don't know what the answer is on that, sir. I know we can improve it, but the question is, can we improve it with some small, simple kinds of corrections, and that is the unknown.

Mr. VOLKMER. Now, on the APU's on STS-9, can you tell us why the failures didn't show up in the previous ground tests?

General ABRAHAMSON. That was a very complex metallurgical kind of examination that took us to the problem, that said that we have a problem called stress corrosion. In order to have stress corrosion, you have to have some stresses that you didn't plan for, and a corrosive element, and we think we know what the corrosive ele-

ment was, although we were not finally able to prove it. Those corrosive elements were not in the ground testing program, so we just flat didn't see them.

Mr. VOLKMER. Was that because of purging?

General ABRAHAMSON. Yes, sir. That was because they were carefully purged after each test. We think that it was exacerbated in this case by the fact that the Columbia sat for that very long period of time as we went through.

What we are now doing is that we will be flying with low-time APU's on this next mission and perhaps even the mission after that, and we have spares that we can do that. Meanwhile, we are going back; we are correcting our procedures to remove the corrosive elements, and we have already done that by adding an ability to purge on the pad and on the vehicle. But, we are also trying to remove the fundamental cause, and that is some of the stresses. These components have an unknown amount of built-in stress, and we are trying to find ways to reduce that as well.

By the way, that is some very pioneering work that is being done by Rockwell and by the subcontractors, and I think that they need a salute for the effort that they are undertaking.

Mr. VOLKMER. Are there any other subsystems or systems of the orbiter where the ground testing procedure does not basically follow what happens in flight procedure?

General ABRAHAMSON. Well, we have got something wrong with the brakes that we just flat don't know about at this point, and that is what I would consider to be the major one where our ground tests have not been borne out in our flight program.

Mr. VOLKMER. Are you making changes in your ground-test procedures to try to determine, or do you have an idea from what is happening in the landing as to what is causing that?

General ABRAHAMSON. The brake problem is a more significant one, and we just absolutely don't know yet. There are two ways to do this. One is to find out exactly what is wrong and try to make some minor improvements to our existing brakes, and we will be fortunate if we can do that. We are also going back and try to fundamentally look at the brakes and build in more margin, with some fundamental changes. That is more expensive, but in the long run, I believe that is what we have to do.

Mr. VOLKMER. On the solid-rocket boosters, are you satisfied now that we fully understand the reasons for high erosion rates incurred in the booster nozzles during the flight of STS–8?

General ABRAHAMSON. Yes, sir. I think we understand that very well. We have corrected the manufacturing line.

It was suggested to me, however—and this is why I made a point earlier—I do believe we have a national and international problem in the work associated with composite materials for rocket motors, in particular. We are not only solving it on an individual problem basis, but we are going back and trying to examine the fundamental issues.

This is an artful kind of manufacturing activity, and I believe that the Nation just must look at it on a much more fundamental view. So we are trying to do that. By the way, that is what NASA is all about, and I think we will do that well. But it does mean that it has implications for the entire solid rocket motor industry. I

think that they will have to begin to build their design models in different ways, and they will have to develop new techniques for inspection, so that we can have more reliable and consistent results.

Mr. VOLKMER. I would just like to ask briefly something that to me—if it worked for, what, 16 PAM's, and we have had 10 flights of the shuttle, the solid rockets and all the test vehicles and everything, then why does it show up now and it didn't show up during one of those other ones?

General ABRAHAMSON. That is the question we are all asking, of course, and it is the right question to ask. It does suggest that something changed in the manufacturing process on a system that was qualified.

But we do know that it was qualified with some very narrow margins, so we don't know what the final answer is yet. I will be delighted if we can get an early answer to this and give you a special report on that, and I will plan to do that if you would like that, sir, and I would be even more delighted if we could get that answer next week, but we don't have it yet.

[The information follows:]

The PAM anomaly experienced in deployment of Weststar VI and Palapa B2 in the STS 41B mission launched on February 3, 1984, is under investigation by the commercial producer of the PAM upper stage with NASA and DOD assistance. As soon as a report of the finding is completed, it will be made available to the Subcommittee.

Mr. VOLKMER. Do you believe that we need to go back and do additional research, basically on the fundamentals?

General ABRAHAMSON. Yes.

Mr. VOLKMER. Not only on design but on the material used?

General ABRAHAMSON. Yes. My view of this national problem in rocket motors is that the design models themselves do not adequately take into account unknowns and variables in the manufacturing process, and therefore we don't build in sufficient margins.

In the manufacturing process, we don't have inspection techniques that are good enough to see those variables happen, and therefore you don't know that a problem has developed until it is too late, and that is the kind of subtle interaction between design, manufacturing, and quality inspection that we have to look at, fundamentally.

Mr. VOLKMER. Do you have sufficient funds in the present budget, and in the 1985 budget also, to do the R&D that is going to be necessary?

General ABRAHAMSON. Yes, sir. This is not expensive work. It is just something that we all have to become aware that there is this broad problem. And by the way, there is. We have had—they are not exactly similar problems, but they are related problems, in the IUS, in this PAM, in the MX upper stage, and in the solid rocket motor booster, and I think they all have some element of this thing that I talked about, this relationship, that needs attacking. It doesn't need money; it needs the awareness that we have a national problem and then experts getting busy and working on it.

Mr. VOLKMER. Now, talking a little bit about inspection, do you plan to continue the 100 percent X-ray inspection of the solid rocket booster motor segments?

General ABRAHAMSON. Sir, we do not do 100 percent X-ray inspection of those items. That was an important question early in the development program, and what it turns out is that while that is a very important thing to do for small rocket motors, because the kinds of voids that you get in the solid rocket—and that is what the problem is. It is just like if you are baking a cake here, you don't want great big holes in it somewhere, because that is where you get an uncontrolled burning and the possibility of a disaster.

When you get into something of the scale of this motor, you don't need to do that because the voids there are small compared to the size of the motor. There was a lot of attention put on that, and there is a lot of history behind it, and it is not just the solid rocket motor for the shuttle; it is also the Titan solid rocket boosters that have the same kind of an issue.

So, we don't think that that requires attention. But that doesn't mean that we are being sanguine about this. I have raised questions about certain stress points here, and we are going back and looking at, we must make sure that this thing has consistent manufacturability and safety for years to come. So your concern is well founded.

Mr. VOLKMER. Now, has the Aerospace Safety Advisory Panel—I just got their report yesterday and I haven't had time to look at it yet, and if you haven't had an opportunity, either, we can pass on it for now—but, if you know, have they looked at the question of the solid rockets, the boosters?

General ABRAHAMSON. They have not looked at it as a panel yet. However, they have looked at the specific problem. They have had experts that participated with us on the specific problem in the large solid rocket booster; and, obviously, prior to the time that we launched, they had to be independently satisfied, those experts, as we had a series of independent experts that had to be satisfied.

Mr. VOLKMER. On the question of spares and the amount that is going into spares, in the past, has any of that been diverted for other purposes, used for purposes of management, administration, other than spares?

General ABRAHAMSON. Well, in this way. For example, we had general-purpose computer problems this time —by the way, anticipated—and that is why it was designed with the redundancy, the five general-purpose computers that are there. There are general-purpose computers that are used in our software development facilities and used on the ground, and they are available for flight operation, if we haven't used all of them up, and that ground requirement is considered when we figure out the total number that we need.

So, in those cases, we have used flight components and used them in ground operations. But there are only a few that that is the case.

Mr. VOLKMER. Now, as we get into the spares cost, and some of us have read—I would hate to read it of NASA—read it of DOD for the expensive hammers and the washers and all those types of things. What steps are we taking to make sure that NASA doesn't get into the same thing as to something that you can buy in a hardware store for 50 cents ending up costing $200?

General ABRAHAMSON. A good question.

Mr. VOLKMER. In the first place, there aren't too many things; I will admit that. When you get into the shuttle, there aren't too many things you can go down and buy at the hardware store or any place. [Laughter.]

General ABRAHAMSON. I would like to at least get on the record my own personal opinion about some of that problem, by the way. Some of that problem—we have essentially shot ourselves in the foot. There are normal costs associated with the management of a logistics program, and let me give you an example. We have made great progress in our logistics effort for the orbiter, and the reason we have is because we have, I think now it is something like 240-plus people at Rockwell that are working very hard and doing a superb job, by the way, of defining that program, negotiating spares contracts with subcontractors, that kind of an effort.

Now, those people—that is a legitimate logistics cost. It is unfortunate, but some of the contracts have been structured in the past in the Department of Defense where those legitimate costs have been spread in an equal way across certain of these components, and on a numerical basis. So, if you are going to buy a $1 million electric component, that little additive cost doesn't look too bad. But if you are going to divide in such a way and add that onto the cost of a hammer, it looks like a disaster.

So, at least a portion—and I am not trying to wish away this problem, because it is a real problem—but at least a portion of what has been, I think, misused in the press about this problem is because of the way we account for things, and they are legitimate costs.

Now, that doesn't take away the whole problem. We do have things that, unfortunately, could have and should have been bought in a more efficient, and hammers could have been bought from hardware stores rather than from going through this kind of process.

I am sure that somewhere in the NASA system somebody is going to come up with some of those. But we are trying to learn from what has happened over there. I have had one personal logistics cost review at the orbiter and at Rockwell with special attention on this, and we have had others. We have audits going on board, and we are issuing directions that say if, in the end, no matter how it seems rational in terms of the way we account for costs, if the result does not make sense, we are not going to buy it that way and we are not going to pay that kind of money.

Now, we may find a horror story here and there in the process, but we are trying to make sure that our management properly deals with that question—both the apparent question that is not real and the real part of it that is just an improper use of funding.

Mr. VOLKMER. Getting into that in a logistics sense, as I understand it, as of last year, there were 23 civil service employees at Johnson involved in overseeing the STS logistics system. Is that correct?

General ABRAHAMSON. No, that is not the STS. I think that is primarily the orbiter. There are other logistics people around the entire system, and I think that——

Mr. VOLKMER. What is the total?

General ABRAHAMSON. I think we need to provide that for the record, sir. We are going to get confused between contractor logistics support people and Government managers.

Mr. VOLKMER. All right.

[The information follows:]

At the Johnson Space Center, there are presently 46 Civil Service personnel supporting our logistics effort. These personnel are broken out as follows:

JSC, Level II: Test & Ground Operations Office—3 logistics.

JSC, Level III: Orbiter Logistics Office—4 logistics, 5 resources, 34 engineering support—43 total.

Mr. VOLKMER. Now, those are the logistics for the orbiter and for making sure that parts are where they should be and where they may be needed, and replacements, et cetera?

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. How many of those are engineers and not basically trained in——

General ABRAHAMSON. Logisticians?

Mr. VOLKMER. Pardon?

General ABRAHAMSON. Not logisticians?

Mr. VOLKMER. Yes.

General ABRAHAMSON. I am sorry. We will get you that data when we supply the other portion of it.

[The information follows:]

Forty five (45) of the forty six (46) personnel are Engineers, the other is a Program Analyst.[1]

Mr. VOLKMER. And as I understand, most of your professional logisticians are located at Kennedy that have to do with the orbiter.

General ABRAHAMSON. We have a group of logistics specialists at Kennedy. We also have a great deal of logistics assistance that is provided through the Air Force in helping us establish this logistics program, and by the way, that is what we are doing. We are establishing a multibillion-dollar logistics program, and that is not done in a short period of time. It has to be implemented over time, and I have done that. Even where we had an entire command, the Air Force Logistics Command, I can assure you it took on the order of years of working with that command support to establish that logistics base for the F-16. So, it is not complete by any means, but it is really ramping up, and I think we are making a great deal of progress.

We do not have within NASA all of the logistics specialists that one would like. On the other hand, we have some superb NASA managers who are learning that activity very quickly.

Mr. VOLKMER. Do you plan to have one center primarily responsible for logistics on the orbiter?

General ABRAHAMSON. At this point in time, our logistics policy is one that recognizes the engineering importance of the base and the management base that is established within each of the projects. Therefore, the primary logistics responsibility for the orbiter; for example, is at Johnson where the project office for the orbiter is. The primary logistics responsibility for the pad and all the Government equipment and things that are on the pad is at

[1] There is no career code for Logistics at JSC. The Logistics effort is contracted. NASA uses "Logistics" Engineers to manage the program.

Kennedy. The logistics responsibility for the solid rocket motor booster is with the development office and the procurement office at Marshall.

Eventually, we will consolidate much more of that activity at Kennedy. What the final outcome is in terms of whether or not you will move all of that engineering capability there and how much you will retain at the other project offices is a judgment we still have to make on a case by case basis as we go ahead.

Mr. VOLKMER. As I look at it, and with the proposal eventually, of course, for the shuttle to forget Edwards and leave Kennedy, it would appear to me that that is where your basic center should be.

General ABRAHAMSON. I think that you are absolutely right where the real support activity is. I was addressing the logistics engineering kind of backup, and so that is where we are tackling that problem.

Mr. VOLKMER. I can understand.

Does the gentleman from California have anything he wants to ask? I have several more I want to do.

Mr. BROWN. You are doing very well, Mr. Chairman. [Laughter.]

Mr. VOLKMER. I have several more to go yet.

General ABRAHAMSON. Yes, sir. You are doing very well, sir. [Laughter.]

Mr. VOLKMER. I want to get into another thing that came out. We have discussed in the past at other hearings, and I would like to get your idea where we are on it, that the NASA Advisory Council made a recommendation that the operating budgets, facilities, and personnel required to support the space shuttle be fenced, basically, from the rest of NASA. It was argued that this would help speed the transition to more efficient operations, help reduce costs, ease eventual transfer of STS operations to the private sector, a new Government operating agency, commercialization, or whatever, and also protect maybe some of the other elements in NASA research from the octopus that they thought would gobble them up. What do you think about the fencing proposition?

General ABRAHAMSON. I think that there may well be a time where that is an important thing to do, and we are working toward that to a significant extent.

In the near term, I think we still need the ability to use funds in a flexible manner so that in fact we can—and let's use the engine as a good example. We are trading off buying more spares, which is an operational kind of budget, from doing some additional development and some improvement for the durability of the engine. As that program goes forward, I think it is important that we have the flexibility to put a little bit more in one side or a little bit more in the other as we proceed. So I think it is premature to do that fencing.

Finally, when it comes time to do that, you may want to do it in a broader basis than NASA, because there is a large DOD input into the budget as well, and I believe that that is worthwhile looking at, and we have tried to anticipate that point in time, and we have a study that we have completed about what that might mean if one did such a thing. So, I guess what I am trying to say is that, No. 1, I think that is a good recommendation from the Advisory Committee. However, it is one that should be implemented in the

future, and we are looking to that. But it should not only be looked at in terms of the NASA budget; it should be looked at in a broader sense as well, and I don't know what a final proper outcome of all of that is. But we are certainly not ignoring their advice.

Mr. VOLKMER. Do you have a study ongoing on this?

General ABRAHAMSON. Actually, we have completed it, and it represents a very knowledgeable consultant's judgment. It does not represent what ought to be yet a final course of action, and the agency hasn't taken any action on it.

Mr. VOLKMER. In other words, you would call it a preliminary study?

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. Could it be made available to the committee?

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. I would appreciate it if you would furnish us with a copy of it.

General ABRAHAMSON. All right, sir.

Mr. VOLKMER. We would like to take a look at it and discuss it even further, because to me some of it does make sense, but I can see the problems in the operations with it, too, but I think we need to be seriously looking at it.

On the question of recompetition on some of the systems and subsystems, how many of them right now are under study for recompetition?

General ABRAHAMSON. Our general policy is that we should look at every element of the system for recompetition. Now, how far we should go in that, whether or not you should actually recompete it, is still an open question.

At this point, I believe some 46 percent of our overall operational costs—and I will correct that number if it is not exactly right, but I think it is on that order of magnitude—that we have competed, and now after competition out in consolidated contracts such as at Kennedy and the shuttle processing contract; and we already are receiving some substantial benefits from that. We are looking at some major ones in the future. One of those will be a consolidation of the major operating contracts at the Johnson Space Center, and since that is a very fundamental and important activity, we believe that that makes sense. It is primarily a labor-intensive task, and it is one that can benefit from both consolidation, and frankly, we want the new ideas that come from competition.

There is a category of what we are calling competitive studies, which means we are not ready to go out yet and say we are going to submit a request for proposal, but those are ones we are looking at, and those include the external tank or portions of the external tank, the engine itself, the main engine, and potentially something on the solid rocket motor production in the future as well, and refurbishing of or refilling the motor cases with propellant.

So, what we are trying to say is that we don't consider at this point that any area of the program should be off limits for legitimate new ideas, or at least be willing to open and look at, can it be done better. But, when I say that, I would also hasten to add that this does not imply that we think people are doing bad jobs now. We think that we've got a great team that is there, and they should not be afraid of some new ideas or even to stand up to com-

petition, because many of these contracts were established as a part of a development effort, some of them nearly a decade ago, and we think it is in the Nation's interest to be willing to look at that.

Mr. VOLKMER. I would like to just take one example, as I look at it, from one part of it that I heard about as a possibility and one I am maybe a little familiar with, too, that is ongoing. Let's take the external tank.

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. Now, to me, from what I understand, that has been a very successful operation considering the ability to produce the numbers that we asked them to do, and in the foreseeable future, it looks like they will be able to produce what they can in reducing the weight and being able to provide the insulation and build it at less cost than was anticipated. Is that correct?

General ABRAHAMSON. Sir, the external tank is one of the stars of the program.

Mr. VOLKMER. Now, what I am asking you is, what do we hope to gain by recompetition?

General ABRAHAMSON. This is an exciting country with a lot of new ideas, and in some cases people with new production capability, and again, as I say, it is not a matter of being dissatisfied at all with the external tank operation. It is a matter of saying that if somebody out there has a better idea to do maybe not the whole thing, maybe even a portion of it, we ought to be willing to let them look at it. Now, as we go through that process, I assure you, even people that are already doing a great job kind of tighten the belt and look at it and see if there is a way to do it better. So they benefit from that competition as well. That is the basis of our policy.

Mr. VOLKMER. Now I would like to get a little bit into our main engines and the NSTL mishap, I guess, a couple of weeks ago on the phase II R&D engine.

Can you tell us how serious that is and what actually occurred?

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. Is it as bad as what I first heard, that the pumps blew up or something?

General ABRAHAMSON. This was a research and development engine and what that means is that it is old hardware. It would never have been flown, so we have not lost key components of flight hardware.

However, what it was doing was, we were testing some of the improvements that are included in this $900 million of improvements for the high-pressure fuel pump.

Mr. VOLKMER. Are we not looking for 109 percent plus long longevity on those engines?

General ABRAHAMSON. Let me make sure that we don't misinterpret the 109 percent.

We have already certified the engines for operation at 109 percent.

Mr. VOLKMER. How long will they last at 109 percent?

General ABRAHAMSON. The problem is that they won't last very long.

Mr. VOLKMER. That is my question. I am saying, aren't we looking for——

General ABRAHAMSON. So we are looking for an objective of something like on the order of 10 flights with those pumps without having to take them back and tear them down. There may be some inspections required, but 10 flights, and we think that that is a good tradeoff place in terms of reasonable improvement. Now, there is a whole series of very minor things that we have already done research on a long time ago, and it was the foresight of this committee and the science and technology people within NASA to establish a program where they have looked at pump seals and bearings and things like that. So that engine had in it, I think, something like 12 of those minor items—and I might have to correct that—but they are minor items, and we were getting just startlingly good results, by the way. We were lowering the operating temperature on that pump by over 100°, and that means it will last longer. So we were really in a good effort, and I was just delighted with it.

Now, what happened I don't know. We have an investigation team that is looking at it. What it has done is, it has wiped out that new pump. We won't be able to use that pump again. There are several other elements of the engine that, internally, were damaged, but it did not blow up in the sense that the engine blew up and all parts of it were destroyed. Several parts are.

The big problem is, of course, is any time we lose a development facility—and that is what that engine was, a development facility—then we have to scramble in order to replace that, and we are going to lose some time. We are probably going to lose between 6 and 8 weeks, maybe even a little longer than that, in order to get that program back and operating, and I don't know what caused it to happen. So there is an impact.

Mr. VOLKMER. If we don't know what caused it, what have we learned from it, except that you have run it for an additional timeframe at lower heat, lower temperature.

General ABRAHAMSON. Well, up until the time that the incident occurred, we had learned that in fact these fixes that we had a great potential payoff, and they are very worthy of continuing that effort.

Now, if one of these fixes turns out to be the problem when the investigation is complete, then we will know that we had better not do that, or we need to modify it or do something. But it is too early for me to say that I know that one of those fixes was the problem.

Mr. VOLKMER. So we still have a ways to go down the road before we get to where we want to go?

General ABRAHAMSON. Yes, sir. Yes, that occurred on the 14th, and, of course, we immediately swung an investigation team in. And they are proceeding in a very systematic manner to investigate that.

Mr. VOLKMER. Now, the same thing as I—not the same thing, but we have the problem with the filament-wound case also, do we not? As I understand it, it's been reported the one that was to be used in tests was dropped. And my question is, Is this going to continue to be a test vehicle?

General ABRAHAMSON. Yes, let me put the filament-wound case in some perspective. The filament-wound case program is one that there was a great deal of skepticism and concern that we could ever build at the reliability levels that we wanted, something of this composite material. So, we had a major effort looking at it—you know, can we build it, can we build it consistently? Remember, my earlier concern with composite materials. And in addition to that, can we inspect it?

We spent a lot of time and effort on that, and I am encouraged that, in fact, with all of the experts that we've had working on it, that we think that we are past that question of, Can we build it? And so I want to get that on the record that we are very encouraged with that part of the program. We have a very tight schedule, and that tight schedule will not allow accidents of the kind that we had. And that was a handling accident. It was the result of carelessness or an improper procedure, I think is a better way of putting it. It did not have a major impact on the program as we go ahead.

Mr. VOLKMER. You will still be able to build that?

General ABRAHAMSON. We believe at this point in time that we will be able to use that for ground tests. We would certainly never use it for a flight vehicle.

Mr. VOLKMER. Now, last year I understand the testimony was that the total average cost per shuttle flight for the fiscal year—that was back in the past year, 1983—was between $225 and $250 million. What will be the total average cost per flight in fiscal year 1984?

General ABRAHAMSON. Yes. We—again, that's a very difficult question because it's an accounting question. What do you want to put in the cost of the flight? Do you want to include the cost of the modifications? Remember, we added modification team working on the Columbia for an extended period at Kennedy, and, you know, do you want to allocate that kind of a cost across those flights? And frankly, we are only now getting an accounting system that separates those kinds of things out from the true cost of a flight. So that's a tough accounting problem.

Our judgment is that we are down on the order of $150 million or so in terms of the cost, legitimate cost, to a flight, this year, and continuing to go down very dramatically. We think we've made major improvements in learning both with increased rate and also with increased efficiency in production lines for such things as the external tank.

The 225 to 250 million was our estimate last year of the R&D costs in 1982 dollars for a 1983 launch. The total cost, which includes R&PM, estimated at that time was $275 to $300 million. The fiscal year 1983 actual launch rate was less than projected and consequently the estimated actual total costs for a 1983 launch were approximately $350 million in 1982 dollars. Our judgment is that we are down on the order of $150 million or so in total costs in 1982 dollars for a launch in fiscal year 1984.

Mr. VOLKMER. Now, what is the reimbursement cost per flight? In other words, DOD dedicates—to get a flight dedicated to DOD, what would be the total reimbursable on that?

General ABRAHAMSON. DOD has a flight charge where they transfer to NASA, in 1975 dollars, $29.8 million for one of those dedicated flights. That's slightly different——

Mr. VOLKMER. No. What would it be this year?

General ABRAHAMSON. OK. In 1982 dollars—I am getting that—it's about $54 million or so. Yes, 1984, about $60 million. And we'll give you an accurate number if you'd like.

Mr. VOLKMER. I am going to come up with one more.

General ABRAHAMSON. OK, sir.

Mr. VOLKMER. Now I'd like to know what are I guess what I'd call the additive costs of each shuttle flight average in this fiscal year? And by that I mean those above those costs that you put in for accounting or development and billing, et cetera, just the additive costs that would be incurred to put a flight up.

General ABRAHAMSON. Most of those additive costs are associated with the production of a tank and the refurbishment of a solid rocket booster motor. And again this is an approximate answer, but we think that's about $50 million in 1983 dollars, or 1983 in those year dollars. And that's going down we think on the order of 45 million or so in 1984, and will continue to go down on an additive basis.

Mr. VOLKMER. Now, those external things, in other words, if you have a shuttle flight that is scrubbed——

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER [continuing]. Do we end up then, if I understand, if we get a $60 million, like we've had a DOD scrubbed this year——

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER [continuing]. We would get——

General ABRAHAMSON. But we're not going to expend the tank, and we're not going to expend the solid rocket motor activities. So what is really lost is the efficiency of the tight schedule that we had set up. And if, for example, on any of the scrubbed flights we reused the planning—and that means all of the trajectory calculations and those things—frankly, it's a very small cost that's lost. The problem is the efficiency factor that's introduced. That's the difficult part.

Mr. VOLKMER. You lost the reimbursement, though?

General ABRAHAMSON. The—what we have is an agreement between—a memorandum of understanding between the Department of Defense and NASA which has attempted to recognize the realities of the budget process in both agencies. And we have stabilized the reimbursement in the budget year and the next year. So we've essentially stabilized it in a 2-year base.

And what that means is that even though that flight will not be flown this year, the Department of Defense will provide the planned-for money to NASA so that, you know, we don't end up short that year in a difficult way.

Now, what happens, and the problem that gets generated, is in the third year out because the Department of Defense——

Mr. VOLKMER. Just a minute.

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. In other words, what you're saying is the planned reimbursements that were to be made in this fiscal year will be made——

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER [continuing]. No matter if the flight doesn't go?

General ABRAHAMSON. That's correct.

Mr. VOLKMER. All right. And also, so I understand better, you've already paid for the external tanks and——

General ABRAHAMSON. Right.

Mr. VOLKMER [continuing]. The solid rockets and refurbishments——

General ABRAHAMSON. Yes.

Mr. VOLKMER [continuing]. And all that anyway.

General ABRAHAMSON. And that's why, of course, that memorandum is generated, because you have to produce that hardware, and that means that contractors have to be paid and people have to take their checks home.

Mr. VOLKMER. I'm talking about the third year where your problems are.

General ABRAHAMSON. Yes. Now, the third year is where the assumption has been that we will be able to make that adjustment properly as we go through the budget process, and there is a credit then that is accrued and moved on downhill to that third year. And it is that crediting, it is the administrative process of adding up those credits and dealing with them properly for changes from the past as well as reductions in the DOD mission model in the future that potentially could create a problem. And it's in the third year out. And there is a problem now that we've identified and we're continuing to work with the Department of Defense.

But there is at least time to make adjustment in the budget process for that.

Mr. VOLKMER. As I understand, the problem may be that because of the—you had a what, just this last year in the fall, we had a cancellation, now we have a cancellation, and continue to have cancellations for which you're being paid for, that those have built up, and we're going to end up owing them money?

General ABRAHAMSON. Yes, sir. Yes, we'll pay it off in external tanks or something that they don't launch. [General laughter.]

Mr. VOLKMER. The next thing that concerns me, from what I have been hearing lately, is again with DOD—and we'll address this a little bit better tomorrow, but I want to see how it impacts if it is true—that DOD would end up going and saying:

> We don't really want the shuttle. We're going to go with ELVs, some Atlas Centaurs, and we're going to go with some Titans that are in the ground and refurbish those or fix those up. We're going to use those from now on.

How does that impact on the shuttle manifest, the shuttle operations and the shuttle costs in 1989, 1990, 1998?

General ABRAHAMSON. Well, the Department of Defense is the largest user of the Shuttle. And——

Mr. VOLKMER. Potentially.

General ABRAHAMSON. Potentially, yes.

And they have had what I consider to be an unrealistic mission model that was built into the shuttle planning very early on, long before the first flight. And each year as we go through the budget process, we are getting a more realistic budget mission model not only from the Department of Defense but also from NASA pay-

loads. And also fortunately, we've been able to fill up some of those things with commercial payloads at this time because we're pretty good marketeers so far. And that's been helpful so long as you can fill those in.

But where those cancellations occur in the near term—you know, if they occur this year or next year, and there just isn't a commercial customer that you can bring in to fill in—then in the end the NASA budget suffers because, to some extent, we don't fly missions and we don't achieve the efficiencies that I talked about.

So that—that is a problem for us. Again, it requires better planning. It requires recognition and proper allocation between both the Department of Defense budget and the NASA budget. And it requires long-term examination of what the meaning of their mission models are.

I think it's appropriate to address to your witnesses tomorrow what their overall intentions are.

Mr. VOLKMER. I plan to, because I think it could have a severe impact on—on the shuttle operations.

Now, as I understand it, in the NASA 1985 budget, that 1.2 or 1.6, somewhere in that range, are reimbursables?

General ABRAHAMSON. Yes, it's 1.2. I would like to point out, so that there's no confusion about what that means, in 1985 the amount of reimbursables which are really the costs that we get in order to launch payloads—and that's what I think most people think about—that's some planned to be $676 million. And a little over half of that is Department of Defense, and the rest is commercial.

Now, there are many other activities that in some cases NASA is doing things for the Department of Defense or other agencies, and in some cases, DOD is doing for NASA. When we add up those activities for primarily the Department of Defense, we find that in order to support Department of Defense activities in coming on board at Vandenberg, there's about $177 million of work that is done by--by NASA contractors supporting the Department of Defense. For the Centaur it's about $153 million. And then, quite separate from the Department of Defense, although some of them are DOD payloads, there's about $97 million associated with our expendable launch vehicle program, the runout of the Thor Delta and the——

Mr. VOLKMER. Now, are those already prepaid?

General ABRAHAMSON. Yes, sir. Yes, sir, those are prepaid. So that $1.2 billion, the way to think about it, about half of it is work that is being done and is really a transfer payment.

Mr. VOLKMER. All right.

General ABRAHAMSON. And about half of it is—is associated with flights of the shuttle.

Mr. VOLKMER. Your ELV and your shuttle would be money that would go back into the shuttle operations program?

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. Did you give us a breakdown as to where that money goes into the shuttle operations program?

General ABRAHAMSON. Well, that's—it goes back in to pay for tanks and all those kinds of—it's not a kitty that we just, you know, can spend anywhere we want on expensive rental cars——

Mr. VOLKMER. I understand that.

General ABRAHAMSON [continuing]. Or anything like that.

Mr. VOLKMER. But you ought to be able to tell me where you plan to use that money.

General ABRAHAMSON. Yes. I will have to provide you that for the record.

[The information follows:]

BREAKDOWN OF REIMBURSEMENTS FOR FISCAL YEAR 1985 IN SHUTTLE OPERATIONS

	Requested appropriations	Assumed reimbursements for standard services	Total requirements
Flight operations	316	159.6	475.6
Flight hardware	758	382.9	1,140.9
Launch and landing operations	265	133.5	398.5
Total shuttle operations	1,339	676.0	2,015.0

Mr. VOLKMER. Is it part of the budget? Is it part of the——

General ABRAHAMSON. But essentially, it goes into the——

Mr. VOLKMER [continuing]. Shuttle operations budget and——

General ABRAHAMSON. Oh, yes.

Mr. VOLKMER [continuing]. We knew, payloads and——

General ABRAHAMSON. Yes.

Mr. VOLKMER [continuing]. Integrating those with the shuttle and shuttle turnaround and all that? If it is, you know, surely——

General ABRAHAMSON. That's what it is.

Mr. VOLKMER [continuing]. You can show us a breakdown because you have to somewhere have a breakdown of that——

General ABRAHAMSON. Yes.

Mr. VOLKMER [continuing]. Where you're going to use it.

General ABRAHAMSON. We do have it, and it's—it's in those areas. It's to pay for tanks——

Mr. VOLKMER. Right.

General ABRAHAMSON [continuing]. To pay for reimbursements on—you know, it's the legitimate operation of——

Mr. VOLKMER. I would like to have it.

General ABRAHAMSON [continuing]. Planning and flying the shuttle.

Mr. VOLKMER. Just—it's just basically like we go back to the big budget book on that——

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER [continuing]. On your appropriated funds, I can find out basically where this money's going.

General ABRAHAMSON. Yes.

Mr. VOLKMER. But I can't do that on reimbursables.

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. I want to make sure that you do the same thing.

General ABRAHAMSON. Yes, the problem is the level of the budget books are you get it at the top level, and there are—the data is available.

Mr. VOLKMER. All right.

[Pause.]

Mr. VOLKMER. On the IUS and its problem along with all the other ones, you touched briefly on it. But can you tell us about where we are as far as being able to use the IUS? It appears that the Defense Department on theirs has given up on it. We've got a TDRS coming up later this year in the fall. Are we going to be a go or no go?

General ABRAHAMSON. Well, we are planning to launch the TDRS in December of this year. And I think that it's still a possibility that that can happen. It's certainly not any assured situation at all. But it's—it's possible. By the way, there is a major IUS review going on today with many of our NASA experts in this area and our key management people out at the west coast, reviewing this with General McCartney of the space division. And some of the answers, more specific answers, you're out of will be—come out of some management judgments made at that meeting.

Mr. VOLKMER. Is there a possibility that they will basically scrap the present design, motor design, and go to a different design? Any possibility of that?

General ABRAHAMSON. I don't think that we're there at that point. That is—frankly, that would be a tragically expensive operation.

But as I indicated, I am disappointed because I think there are some very fundamental problems, and there aren't just some nice, slick, easy solutions. But we've got some of the best people both in NASA and in the Air Force and the contractor teams trying to find ways around this and to salvage the situation, salvage what was clearly a deficient design in the beginning.

Mr. VOLKMER. Do you have any major problems so far with the shuttle Centaur, Centaur development?

General ABRAHAMSON. No, sir, that's coming along pretty well. But I would like to ask Mr. Moore if he would like to give some specifics on that.

Mr. MOORE. Yes, I will just give you a couple of specifics. We finished our critical design review on that in 1983 on the D-prime vehicle, which is the large 28-foot version. We're getting ready to do a preliminary design review on the G version, which is the 20-foot thing.

Our first opportunity, the planetary launch is coming up in the May-June timeframe in 1986, and we see ourselves on track to make that, although the schedule is tight, you know. But we think we're going to make that OK.

Mr. VOLKMER. You see no major technology problems at this time?

Mr. MOORE. No, sir. I think we've got a very good working relationship with the people working the orbiters to make the mods on the orbiter as well as the Cape in preparing for the second pad, as well as a good working relationship with DOD on it.

Mr. VOLKMER. OK. Now, we've touched a little bit on discussing cancellation of the shuttle flights of DOD on the pricing policy and prices charged DOD. Do you believe that that pricing arrangement is fair to NASA?

General ABRAHAMSON. I think it is fair to NASA, sir. It was established in terms of the amount. It was established based on in-

vestments that the Department of Defense made in the overall shuttle system and in considering those kinds of things. So I think that it's fair in that sense.

I think what we have is a technical and administrative problem in working out the timing of funding. And we, in addition to that, we have a problem in coming to a realistic workable level of planning for Department of Defense launches.

And by the way, this is something that often happens, obviously, in Government. Some of these delays are because of alternate plans for the—for the vehicles, such as—as moving a small number of payloads to—potentially—to an expendable launch vehicle. Others are some of the technical problems that happen when you have a launch that's planned on a particular time and either you're not fully funded or you run into a technical problem and it's delayed and then it moves on downstream, kind of the natural tendency of things to move to the right. And our problem is in mutually negotiating and looking ahead and making those judgments in a way that our budgets can properly reflect that. And that's what we're—we're getting better at, but aren't yet there, frankly.

Mr. VOLKMER. Now, the filament-wound solid rocket booster, the need for weight reduction, et cetera, that's supposed to be used for Vandenberg flights, is that going to be reusable?

General ABRAHAMSON. Well, the RFP that we sent out, and the program objectives, are to make that a reusable stage. However, that's really a tricky area of technology, and we are not—we're not exactly sure how to proceed with that at this point in time. Frankly, the way we're going to do it is that it's being designed and built with sufficient margin that it will be reusable.

The questions are: After it's dumped in the ocean and after it's used and gets beat up just a little bit, how can we assure ourselves that indeed that, those margins are still there and still safely in this kind of composite material?

So the way we'll approach that is kind of very carefully—we'll try it once and then take a very careful look at it.

Now, that's why we're paying so much attention to inspection methods in the development of the program, so that we'll know the baseline that we have. And then we'll dunk it in the water and see what it looks like when it comes out, and have to make some very careful judgments about how we proceed with that. And as I say, it's an experience-based program as opposed to one that you can just simply plan on.

So we don't know what the amount—what the reusability factors will be. Obviously, it's important that it is reusable because they're expensive stages. And if it's not, we'll just use it a few times.

Mr. VOLKMER. Yes. If it is not reusable, what does it do to the costs of the flight?

General ABRAHAMSON. Yes. Let me see. We'll have to give you that number. But I believe that the cost of the solid rocket booster—I've seen a factor here—and I believe that the cost of the solid rocket booster goes up by two or something like that, two or three. I'll have to give you a number.

Mr. VOLKMER. I would appreciate that.

[The information follows:]

The current total cost for a flight set of all new SRB hardware flown in FY 1985 is approximately $57M. Exchanging filament wound segments for steel segments would add approximately $2.5M.

General ABRAHAMSON. It doesn't double the cost of the total flight or anything like that, but it does add several of millions to the cost of the flight.

Mr. VOLKMER. And then the question is, if you do that on DOD flights, are we going to get reimbursed if it's not reusable, or are we just going to be stuck with the earlier agreement?

General ABRAHAMSON. Yes.

Mr. VOLKMER. That's something to think about.

General ABRAHAMSON. I think that's a question that you—yes, sir. OK.

Mr. VOLKMER. All right.

General ABRAHAMSON. Yes, we will probably want to use that on certain NASA flights as well, not—not only for the Department of Defense.

Mr. VOLKMER. Boy, I don't know if you're prepared to answer this one. If you're not, perhaps you can give it to us, as long as you're going to have to provide this other information, too.

If we were to add money for a fifth orbiter during the 1985 budget cycle to start, what is the funding increment that would be required to get no additional downtime or loss of prime contractors or subcontractors?

General ABRAHAMSON. Sir, I—yes, I think we'll have to get back and provide that for the record.

Mr. VOLKMER. I appreciate that. Assuming that we keep the same amount of money in for parts——

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER [continuing]. That we have at the present time.

General ABRAHAMSON. Yes, sir.

[The information follows:]

The balance of funding between the in-house effort and subcontractors in the FY 1984 and FY 1986 timeframe retains many essential elements of the Orbiter build capability. However, the Downey/Palmdale assembly workforce will be phasing down with the delivery of Atlantis, scheduled for December 1984, and we will experience some loss of production capability in the final assembly area. Operational and structural spares provisionings have been made to minimize the loss of capability with subcontractors.

Our current assessment shows a one year delay in buying a fifth orbiter would result in an additional cost of approximately $200 million.

Mr. VOLKMER. Now, in your statements I read, you address the program that's going on in the Getaway specials and—and I was over at Goddard just last week and saw the Spartan and the Getaways that's working. But I still have some problem with talking to some of the scientific community about the cost factor and them being able to use it in place of the sounding rockets.

And when will we be in a position to say that some of the things—not all, but some, because some won't want to—but some of those things that have been flown in the past on sounding rockets as payloads, be flown on the shuttle and be able to do so at the cost that the investigators would be able to afford? I am talking about your private investigators and the university community.

General ABRAHAMSON. Yes.

Mr. MOORE. We've had—we've had under study for a while a program called the Hitchhiker program, which is a carrier concept to allow us to get payloads quickly on board the shuttle—for example, light rocket-class payloads do not go to very lengthy integration processes and can fly on a space-available basis. We have just approved at Goddard a couple of weeks ago part of the Hitchhiker program, which is a shuttle payload of opportunity carrier which Goddard is now working on, and will have available within a year or so to fly some of these low-cost rocket payloads on very quick turnaround basis.

We agree we need to do more work in this area, and we are studying that very carefully to minimize the amount of time it takes to get payloads on board the shuttle and to use what space we have available on the shuttle to fly these kind of experiments.

Mr. VOLKMER. So we're talking about 1 to 2 years?

Mr. MOORE. Roughly 1 to 1½ years. The timeframe that we've asked Goddard to come back with its carrier development and be prepared to fly it on like a 6-months notice; for example, or maybe on a standby notice if we have a payload available.

Mr. VOLKMER. And what are we talking about? Any idea whether we're talking about as to the cost factor beyond?

Mr. MOORE. The cost factor is being worked at this point in time right now, but it would certainly be a lower cost factor from a—if you looked at it from a commercial basis than it would be as a regular customer on a standby basis.

Mr. VOLKMER. I would hope so.

Mr. MOORE. Yes, sir.

Mr. VOLKMER. That it would be less than——

Mr. MOORE. Yes, sir.

Mr. VOLKMER. By the way, do you believe there's sufficient funds to continue with this in the 1985 budget to—with the development of this program without——

Mr. MOORE. Yes, sir; we are funding this out of our spacelab activity, and we think there's adequate funds to cover this.

Mr. VOLKMER. Oh, I've been handed something here from the Aviation Week and Space Technology. And see if you can correct me or correct it or comment on it.

NASA has just instituted a procedure requiring all photographs of the Earth taken from the space shuttle go through a security review by Defense liaison office before they are released to the public.

Is that correct? Now, I don't know if you're in charge of that. Maybe we should ask Mr. Beggs, but if you're not familiar with it——

General ABRAHAMSON. Yes.

Mr. VOLKMER [continuing]. Or if both of you are, I would like to know.

General ABRAHAMSON. As a matter of policy, in the past, all of the photographs have been made available to the public. We want to keep that policy. We think that's a good policy. By the same token, I think that we don't—we don't want people to misinterpret and think that the shuttle is a reconnaissance vehicle and/or used for those kinds of—of purposes at all.

And therefore, you know, even though we give the astronauts a great deal of latitude to take pictures of what they think is interesting, we think that the appropriate thing for them to take pictures of are obviously interesting natural phenomenon.

And in that case, now what we will be doing is we'll be cataloging all of those things first rather than just making them available just right off the cuff as we go ahead.

But our intent is not to change the fundamental first precept that the program was built on, and that was to, No. 1, give the crews the ability to take photographs that they think are—are meaningful, primarily scientific or—or even just from an aesthetic viewpoint, and second, that they'll be made available to everybody.

Any other aspects of that procedure, I guess I will have to provide for the record that I am not familiar with.

Mr. VOLKMER. Either that or perhaps we should address a letter to Mr. Beggs on it. But in general, it still appears to me that my question hasn't really been answered——

General ABRAHAMSON. Well, I'll make——

Mr. VOLKMER [continuing]. As to whether there is such a policy.

General ABRAHAMSON. I—I've answered it to the extent of my—my knowledge at this point, sir, and——

Mr. VOLKMER. All right.

General ABRAHAMSON [continuing]. I'll—and we'll provide the rest of it for the record.

[The information follows:]

The statement that NASA has instituted a procedure of requiring that all photographs of the Earth taken from the Space Shuttle go through a security review by the Defense Liaison Office before they are released to the public is misleading.

Anticipation of the increased amount of photography expected to result from the growing number of scheduled Shuttle flights led to a NASA Headquarters review of procedures for release of this information into the public domain. This review concluded that a prudent public affairs policy required the identification of photographs prior to public release with a better system for organizing the photos by broad subject category.

As in the past, NASA's objective is expeditious release of its imagery. No photography has been withheld from public disclosure.

Mr. VOLKMER. It would appear to me that if the pictures taken by the astronauts, even with some hand-held cameras that they take up, are going to be censored by the military first to determine this type thing, it would appear to me to lead everybody to believe that maybe we are using it for military purposes and surveillance. And maybe if it's not open to the public, maybe somebody is up there taking things on behalf of the military and then coming down and turning them over to them and probably can't look at them so——

General ABRAHAMSON. Yes.

Mr. VOLKMER [continuing]. I think it does have some implications that——

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER [continuing]. I think—well, let's put it this way: I'll be continuing to look at it because I want to know some answers.

Now, I have another, one last question here, unless the gentleman from California has any more.

Mr. BROWN. After you've finished, Mr. Chairman.

Mr. VOLKMER. All right. I may keep going. The way it's going, I may keep going. [General laughter.]

Now, if there was a serious—and I guess by serious we could go anywhere from a flameout and a ditch in the ocean or over in Africa to, you know, a landing with a wheel collapsing and tearing up a wing and everything else, a serious accident of an orbiter—would you continue to launch? Let's say that the *Columbia* had this accident, would you continue, you know? Next month, if you go on with the *Discovery* or *Challenger,* would you go ahead and send the *Challenger* or *Discovery* up if something like that happened?

General ABRAHAMSON. Well, I think it's not something that we could answer on a just flatout and say that forever more we'd do that.

First of all, it's been a policy, and I think you've seen it in action, that we will not launch the shuttle and endanger the astronauts' lives nor—nor take chances with the shuttle. And that is our fundamental ground rule. It must go, and it must be a safe flight as we go ahead. Now, it is potentially possible, of course, that—that we could have an accident of the kind that you've talked about. And in that event, what we would do is what we have always done and what happens in the case of an airliner that crashes and involves many more lives than are involved in the shuttle. We would put together the best investigating team that we have, and we would go quickly into that investigation and try to properly deal with it.

If there were any indication that there was a generic problem, then obviously we would not fly in the short term. But I would like to add something that I think is very critical and important here. And that's that the shuttle, we know more about every shuttle flight than any launch vehicle ever had. We know more in terms of the information about that flight because it's instrumented. We know more because we get the parts back.

And clearly, a good example of that is the—is the solid rocket booster. You know, if that solid rocket booster problem had occurred—and it may have—on an expendable launch vehicle, nobody would ever know it. And nobody would ever know it until it finally went far enough to cause a failure. But we get it back. In fact, the only part of the vehicle that we don't get back is the external tank, which, frankly, is not a high-risk area.

And third, we have crews on board to give us information. So that my personal judgment is that even in the event of one of these terrible disasters where you do have an accident, you will probably know more and more quickly so that you can safely reinstitute the flight program than we will ever have had in the past. And, in that sense, there is a scare factor that people have used about manned flight that I think is entirely inappropriate, that what we've got in manned flight is a philosophy of defense in depth that—that's—that's apparent in our design.

It's apparent in a design, for example, in solid rocket modes of booster, where we had factors of safety of two in some of these areas and were able to quickly work around it and solve the problem. And those kinds of factors of safety do not exist in—in some of our past vehicles.

And it's apparent in the way we run the flights. And that should not be discounted.

So certainly, we wouldn't ever commit an orbit in an orbiter or a crew in an unsafe way.

Mr. VOLKMER. I now recognize the gentleman from California. I think I've finished.

Mr. BROWN. Thank you, Mr. Chairman. You haven't left much unfinished, I'll say that. [General laughter.]

General, you mentioned that for 1985 a majority of the shuttle cargo would be DOD cargo.

General ABRAHAMSON. No, sir; no, sir; no. About 25 percent is a quick way, but I'll get you before we finish here, sir, the actual number of flights.

Mr. BROWN. I thought that was in your statement.

General ABRAHAMSON. Oh, yes, I'm sorry. I—I mentioned—and this may be what you're reflecting—that the reimbursements are about half-and-half in that year for the flight. And that's because the difference in the pricing policy and the stability factor that I talked about where we're carrying forward into 1985 flights, or the expenditures in the planned payments for flights that aren't going to be flown.

Mr. BROWN. Well, I meant to ask you about the pricing policy. From that I infer that the——

General ABRAHAMSON. OK, let me just give you the specifics so that you can orient yourself, sir. In 1985 the plan at this point is that there are two DOD flights, dedicated DOD flights; three NASA flights; five foreign and commercial flights; and we have two that are part of our pricing or our manifesting policy, which we're calling reflights. And what that means is that they're sitting there; we may not fly them; but they provide the surge capability in case one of our earlier flights do not fly. And there's a time in the manifest and a place so that if either a DOD flight or perhaps a—a commercial flight or a scientific flight has a problem, then we can easily make an adjustment and stick it in and get it off.

Mr. BROWN. All right. I think I understand the picture then. It's not a majority of the flights, but a majority of the reimbursable——

General ABRAHAMSON. About half of the reimbursable, sir.

Mr. BROWN. And is that going to be typical for the next few years? That's the next question. Or are we on a steep curve, or what is this?

General ABRAHAMSON. No. As you go out into—yes, let me say, 1988, as an example, our capability that we're operating on out there is some 23 flights. Of those, seven are for DOD, seven are for NASA, five are foreign and commercial, two are for reflight, and two are not filled yet and they're—you know, we're in the process of still getting customers for those. And those will probably be foreign and commercial.

So you can see that, actually, the percentage is about a third to a fourth as we go out in the future.

Mr. BROWN. When you describe a flight as a NASA flight, what does that mean? Does that mean there are scientific experiments on it that NASA is paying for or——

General ABRAHAMSON. Yes, sir. It is a fully funded NASA flight such as our spacelab flight in November.

Mr. BROWN. When you—when a flight carries commercial cargo, the commercial owner is charged for that. And my question is, Is that charge comparable to what the DOD pays, or is it less, or is it more? I shouldn't have to ask this question.

General ABRAHAMSON. It's more, sir. And that reflects the—the pricing period from 1986 through 1988 is one where it's about 25 percent more. And the difference there reflects the recognition that the Department of Defense has invested in the shuttle program. And so that's kind of the ongoing investment and the quid pro quo associated with that.

Mr. BROWN. I can understand there are a lot of sophisticated reasons for having differential pricing. What about university researchers that want to take up space? Would they pay a price less or more than DOD or commercial?

General ABRAHAMSON. Yes. It depends on the way it's—it's funded. Let me put it this way, sir. The majority of our—of our university research programs in those kinds of experiments are experiments that come under our State science program. They are, in fact, totally funded through the NASA State science budget. And so it's not only the instruments that are paid for—the development of those instruments—but also the people to operate them and reduce the data, et cetera. Now, in addition to that, in my budget is carried the money for the tanks and the operations to put those up, so that—so the majority of those kinds of university programs are—there is no charge to the university itself. That's part of our ongoing science program. Now, we are trying to introduce, with the Hitchhiker program—and certainly, we already have with our getaway specials—we have some very low-cost ways that people that are not funded in this way through the science program can get onboard the shuttle. And those prices are—are—are really so low.

Of course, they're restricted. They're not, you know, the scope of experiments that you deal with as we deal with on the—on the funded program. But those prices are so low that, you know, they really facilitate and encourage people to come. And that's our intent. We think that's the right way to run the program.

Mr. BROWN. I have no disagreement with that.

Getting back to the DOD cargoes or launches for a moment, those are presumably classified so that we don't know what's being launched there. Is that right?

General ABRAHAMSON. Yes, sir. There is a general classification policy that covers all of those payloads, with the exception of some small communication-type satellites which are—are usually the global positioning system satellites and—and those are unclassified.

Mr. BROWN. Those are unclassified. But the Earth-observing satellite would be classified, those kinds of things?

General ABRAHAMSON. Yes. All—all except for these global positioning systems fall under an overall blanket classification system.

Mr. BROWN. Getting back to this question on recompetition for contracts for just a moment, what kind of contracts are we talking about? Are these fixed-price, cost-plus, or some other type of contract?

General ABRAHAMSON. Our intent is wherever possible to move into a cost-plus-incentive-fee contract. The most common NASA contract in the development phase of activities is a cost-plus-award fee. And I think that's very appropriate for those types of contracts.

However, as we get into a production program where the contractor has to make judgments on his own and he has to be able to say, "Look, if I invest so much money in a tool—in a tool here, I need to be able to predict that I'm going to get my return on that investment." And that's why we think that going to an incentive contract is—is one that he can predict and make, then, good economic judgments that will be in all of our benefits or benefit everybody in a way that they can look ahead to.

Now, eventually, as production really becomes very routine, hopefully we can go to fixed-price-incentive contracts. But that's downstream, frankly, for these kinds of items.

Mr. BROWN. I am trying to justify recompetition in a situation such as you referred to with the external tanks, where you're satisfied with the contract, recompetition can only be an extra burden on a satisfactory contract. Is it your feeling by opening that up to recompetition, that you may get another contractor who will bring a different manufacturing concept or invest in—in tools that the first contractor doesn't have, or in some other way give you a lower bid on that contract?

General ABRAHAMSON. Yes, sir. That—because various contractors have different capabilities, they are located in different parts of the country where there are different labor bases, and because some of them already have invested in certain tools that may be helpful for certain parts of these, we think that that does make sense.

But it—remember, we're not going to do this in a careless way. We're going to do this all very, very carefully, and price will not be the only item that will be considered. You know, overall performance of the contractor as well as the quality of his material is a very important item.

And since you asked about the kinds of contracts, let me indicate what we have done. For example, in the shuttle processing contract down at Kennedy, while we have gone to a cost-plus-incentive contract for that—that consolidated effort, we have a very large performance incentive there, too, so that he understands that he can't sacrifice quality or reliability of performance in order to go for that extra little dollar of profit.

So we think that it's a balanced procedure that we're establishing.

Mr. BROWN. I have great confidence that you will carry it out in a balanced way, but I can see how your first contractor who's done a satisfactory job and may not even have made a great deal of money on it, depending on the circumstances, may feel that another contractor is going to benefit from what he has already accomplished, going to at least get partway up the learning curve because of what he's done.

General ABRAHAMSON. Yes.

Mr. BROWN. And that that's an unfair advantage to a second contractor. It may not necessarily be true, but I can visualize a lot of

contractors feeling that way, particularly when they have done well and, we'll say, invested a lot and not made a lot of money and then lose the contract to somebody else who comes along and takes off where they left off, in a sense.

General ABRAHAMSON. Sir, the point that you're making is a valid concern. And the way that we try to counteract that in our source selection procedure—now, every one of these won't go all the way to a source selection. In some cases where we've just run a competitive study and we look at the—you know, that's just kind of a look ahead—it doesn't make sense to do the next step.

But if we did go all the way to a request for proposal and a formal competition, we have always included now in each of these contracts what we call a past performance criteria. And obviously, if the contractor is really doing an exceptional job, that's where, you know, being on the spot and being the man who's in the ring doing the job, and if he's doing it well, you know, those are points that somebody on the outside, no matter what their good ideas are, are going to have a hard time overcoming.

So there is a method that's well established in our procurement methodology that allows you to deal with that, I hope just as fairly as we can.

Mr. BROWN. You've learned to deal with contractors who want to, say, buy in cheap on a contract and then make it up later?

General ABRAHAMSON. Yes, you know, that's—you know, that's a traditional kind of problem and a worry in every case. And that's, in fact, why in both defense contracting and in NASA contracting, this past performance and evaluations of what they really can do are—are an important element of the source selection process.

So I have personally been a source selection official on several where we did not just automatically select the lower bidder. In fact, we selected a more expensive one because we thought that's where we're going to get the right product and we were not confident that the lower bidder was going to come in where he expected to.

Mr. BROWN. You probably learned then by now that there's no perfectly satisfactory way, that some Congressman is going to criticize you no matter what you do. [General laughter.]

General ABRAHAMSON. No comment, sir.

Mr. BROWN. General, I don't know whether you were going to follow up on this question the chairman asked about those space pictures. I am rather interested in that.

General ABRAHAMSON. Yes, sir, I will.

Mr. BROWN. And if you could in your generosity provide a half-dozen or so sample photos so that we can see what needs to be censored, I'd appreciate it.

General ABRAHAMSON. Yes, sir. [General laughter.]

Mr. BROWN. If we could get sensitive information with a hand-held camera out at the shuttle distance, we may be in trouble. [General laughter.]

Mr. BROWN. I have no further questions, Mr. Chairman.

Mr. VOLKMER. Thank you very much, General. I have no further questions. And I would appreciate your furnishing us the other information we requested as soon as possible.

General ABRAHAMSON. Yes, sir.

Mr. VOLKMER. And I appreciate your being here today and spending all afternoon with us. It's been very helpful to us as we continue on down when we get into the markup later on on this part of the NASA budget.

General ABRAHAMSON. Sir, we—we always appreciate, obviously, the support of this committee and, I think, the—the proper oversight in terms of asking some good, tough questions as—as we go ahead.

There is an editorial comment that I would like to make, and maybe it's because I'm an optimist, but maybe—but I think it's realistic, and I think it ought to be considered.

Many of your questions very properly dealt with some of the problem areas that we have had in the last year.

Mr. VOLKMER. They're concerns. I'm sure they're concerns of yours.

General ABRAHAMSON. Absolutely, they're concerns. And there are probably two ways we ought to look at that. I've tried to answer you in terms of the ongoing actions and how it is that we are trying to solve these various problems, and solve them permanently for the future, not only in the narrow sense of the shuttle itself, but in the broader sense of U.S. leadership in technology. But, I think there is a perspective that's an important one for the shuttle program. We're in a phase of the program that if I were here testifying on the F-16 or on a Department of Defense program, I'd say we're in an operational test and evaluation phase. We have only had 10 flights. We're operational in that we're doing a given job. We're bringing income back in for shuttle services, but we are carrying out the responsibilities that the shuttle program was designed to undertake.

But nonetheless, we do have some of these problem areas. I think the right perspective on these is to look at what this team has really done. It's a question of making the hardware operational, but more importantly, it's a question of do we have an operational team here? And the press has asked me that question, and I would like to get it on the record here that I think this team is indeed operational.

And if you look at how quickly we have indeed overcome several of these key problems, very fundamental, very difficult problems, and then maintained our schedule, if you, you know, were where we were at the end of the STS mission, STS-nine mission, and looked out and said, "My gosh, we had a fire in the back of the orbiter, and—and two computer failures that we don't understand," and then said, "Should we commit, and could we plan for, very nearly an on-time launch at the end of January," we did it.

We had a slight delay in the ninth mission. It would have been about a 2-week delay except for the scientific window associated with that. When we came back and found these—these gaping holes in these problem areas in the solid rocket booster.

But I am proud of this team that was able to find these unknown problems and overcome them and maintain our schedule. Now, it's going to get harder and harder in the future as the schedule gets tighter and tighter. But nonetheless, hopefully, the problems will get less, too, as they come.

So I think that the perspective that we all should be keeping in mind and the one that I am very proud of, is that this contractor team and this NASA team has overcome these problems in a way that's maintaining the schedule.

Now, we've got another difficult one that we have to tackle on a national basis with this upper-stage PAM. I think we'll do it. There may be some slight delays. But I think we'll solve those problems, too, because of the power of this team. And I am proud to have that team and be part of it.

Mr. VOLKMER. Thank you very much, General. I quite agree with you. I think it's been a very successful one.

You mentioned the development stage cycle of the F-16. I am sure that we would not have put the F-16 into combat after its first flight or its first test flight, but what we have done with the shuttle, of course, is put it in operation while it's basically still under development and the components are under testing yet. So there are some unknowns and a lot more unknowns.

So I want to, for one, congratulate you as—and the rest of the team as well as the contractors for so far a job well done. And I am sure it will continue that way.

With that, the committee will adjourn until tomorrow morning at 9:30.

[Whereupon, at 4:08 p.m., the subcommittee recessed, to reconvene at 9:30 a.m. on Thursday, February 23, 1984.]

1985 NASA AUTHORIZATION

THURSDAY, FEBRUARY 23, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 9:41 a.m., in room 2325, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Present: Representatives Volkmer, Nelson, Dymally, Mineta, MacKay, Lowery, Chandler, Bateman, and Walker.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

Today the subcommittee continues its hearings on the NASA fiscal year 1985 budget request.

The organizations represented today play a significant and important role in the space program and certainly influence program planning and direction. The Air Force serves as the agent for the Department of Defense in coordinating with NASA on activities related to the Space Transportation System. Also represented here is the European Space Agency, which developed the spacelab and cooperates with NASA on several science and applications programs. The third organization we will hear from is the Aerospace Safety Advisory Panel. This panel was established by Congress to provide outside expert advice to NASA on safety issues related to space and aeronautics programs.

Our first witness, representing the Air Force, will be Edward C. Aldridge, Under Secretary of the Air Force. He will be followed by Ian Pryke, head of the Washington office of the European Space Agency, and then Willis Hawkins and John Brizendine, the retiring and incoming chairman of the Aerospace Safety Advisory Panel.

Gentlemen, it is a pleasure to have you with us today, and we look forward to your testimony.

Does the gentleman from Pennsylvania have any opening statement?

Mr. WALKER. No, Mr. Chairman.

Mr. VOLKMER. With that, we will proceed.

Secretary Aldridge, your statement, which you have been so kind to furnish us, will be made a part of the record. You may proceed with either reviewing the statement or summarizing, however you so desire.

34-202 O—84——42

STATEMENT OF HON. EDWARD C. ALDRIDGE, JR., UNDER SECRETARY, OFFICE OF THE SECRETARY OF THE AIR FORCE, ACCOMPANIED BY DR. CHARLES COOK, DEPUTY ASSISTANT SECRETARY FOR SPACE PLANS AND POLICY

Mr. ALDRIDGE. Yes, sir. Thank you, Mr. Chairman.

I welcome the opportunity to address the questions raised in your letter of January 16 and to discuss the Air Force space participation in the development of the Space Transportation System.

I am accompanied by Dr. Charles Cook, the Air Force's Deputy Assistant Secretary for Space Plans and Policy.

I have prepared a formal statement, as you mentioned, which, with your permission, I will submit for the record.

But for the brief time available this morning, I would like to summarize the highlights of that particular statement and use most of my time to explain the Defense Department's planning for assured access to space.

Your letter posed questions relating to activities and status of the Air Force Space Command facilities at the Vandenberg Air Force Base and the Centaur program. In all of these efforts, I am pleased to report that we are on schedule and proceeding with no significant problems.

Activation and transfer activities for the Air Force Space Command have consistently been ahead of schedule. The space command now operates and is responsible for 4 bases, 22 sensor sites, and 2 operational satellite systems. Additionally, they have been designated operational manager for two future military satellite programs.

At Vandenberg, the west coast space shuttle launch facility is on schedule and should be ready to support an initial launch capability in October 1985. The schedule is tight, but the facilities to support the orbiter are about 95 percent complete, and we will start ground system tests in May of this year and begin flight compatibility tests in November.

The joint DOD–NASA Centaur program is also progressing very well. The overall program is on schedule with cost tracking estimates very well and all milestones being achieved.

Mr. Chairman, you asked that I address possible Air Force requirements related to the new space station initiative. As you know, we have been working with NASA on the space station concept for over a year, as well as conducting internal Air Force and DOD studies in an attempt to identify military requirements. Our efforts to date have not identified military requirements that would be uniquely satisfied or significantly enhanced by a space station. But now that the President has chosen to initiate a program, we plan to continue our studies and examine potential capabilities which may satisfy future requirements.

Mr. Chairman, for the remainder of my available time I would like to address the subject of defense space launch strategy, which includes our views on the Space Transportation System and where we want to go with both the shuttle and the use of expendable launch vehicles or ELV's, as we call them.

The Department of Defense, unlike other organizations, has a validated requirement for an assured access to space and the infor-

mation and capabilities derived therefrom. When we committed to the Space Transportation System for our sole access to space in the mid-1970's, the anticipated planning factors and costs indicated that there were reasonably acceptable risks in the STS program to meet our requirements.

However, current planning factors—actual cost, actual experience, and revised policies affecting our use of space—challenge the validity of the original decision on the STS program.

The Secretary of Defense has stated that in his opinion the decision to be totally dependent on the STS was a serious mistake. Let me outline some of our concerns.

If things worked perfectly, the current mission model and our current plans for use of the shuttle would not require modification. Under these conditions and with our preemption priority, defense needs could be met with the current fleet of orbiters. However, space systems do not work perfectly, as the recent shuttle flights all too well demonstrated.

More importantly, launch schedules change, and sometimes we have unpredictable failures of spacecraft on orbit necessitating quick replacement. And sometimes even on-orbit successes, which extend satellite life, have a complicating impact because they delay the launch of a replacement satellite in an unpredictable fashion, unless, of course, we want to destroy an effective satellite.

All of this comes at a time when the Defense Department is accelerating and increasing its dependence on space systems for several critical missions, for which there are no nonspace alternatives.

Furthermore, our national space policy calls for more survivable space systems across the spectrum of potential conflict.

For these reasons, we must have complete confidence that we possess an assured capability to launch our systems when required. A total dependence on the shuttle may not provide that assurance.

We note that currently only two orbiters will be able to launch certain future defense payloads. The flexibility to integrate payloads into the orbiter is not as we anticipated when we committed to the shuttle, and operational launch rates have not yet been demonstrated.

Most importantly, the Defense Department has concluded that we need insurance against possible shuttle failures, fleet outages, and system vulnerabilities. This fundamental concern would exist regardless of the size of the orbiter fleet.

Another related concern has to do with the increasing cost of getting our payloads into orbit. Over the years we have observed a significant rise in the fraction of the space system cost which is devoted solely to launching our spacecraft. This increase has, unfortunately, been at the expense of our mission payloads. Lower launch costs, which would permit funds for a greater robustness in spacecraft payloads and production rates have not been demonstrated. We are, therefore, even more dependent upon an assured on-time launch capability because of our limited number of satellites.

While the DOD is fully committed to the shuttle, total reliance on the shuttle for sole access to space, in view of the technical and operational uncertainties, could represent an unacceptable national security risk. DOD believes that a complementary system is necessary to provide a high confidence access to space.

In addition, the limited number of unique manned shuttle vehicles render them ill-suited and inappropriate for use in a high risk environment.

The solution to our requirement must be affordable and effective, and yet offer a high degree of requirement satisfaction, low technical risk, and reasonable schedule availability. Unmanned, expendable launch vehicles meet these criteria and could satisfy DOD operational needs for a launch system which complements this STS and extends our ability to conduct launch operations further into the spectrum of conflict.

I would like to note that the loss of a single ELV affects only that one mission. It would not degrade future common national security capabilities, as would the loss of a reusable launch system.

The President's policy on the commercialization of expendable launch vehicles states that:

> The goals of the U.S. space launch policy are to insure a flexible and robust U.S. launch posture, to maintain space transportation leadership, and to encourage the U.S. private sector development of commercial launch operations.

Consistent with this policy, the DOD is studying the use of commercially procured ELV's to meet its requirements for improving its assured launch capabilities. The plan we would like to pursue is simple, inexpensive, and satisfies our needs. It continues to use the shuttle as our primary launching means, but we are also now investigating the use of complementary but a small number of ELV's. We would continue to plan about 8 to 10 missions a year on the shuttle, but would complement this with 2 ELV flights per year.

Some 90 percent of NASA's mission model would remain the same. A major advantage of this approach is that the ELV's would be used to reduce our launch-on-demand flights on the shuttle going to geosynchronous orbits, those which use the Centaur.

The shuttle would continue to be the primary launch means for those DOD missions in which man provides a unique capability, such as from Vandenberg Air Force Base and those missions more suitable for routine flights which lend themselves to advance scheduling, such as the initial launches of the Global Position System and the Milstar Constellations.

The resulting reduction in DOD launch-on-demand flights would permit NASA to schedule the shuttle for more effective and more routine, multiple payload flights. It would also appear that other users would be more attracted to the shuttle under these conditions since it greatly reduces the threat of DOD preemption of STS flights, and it would provide inexpensive ways to put smaller or commercial or civil payloads into orbit.

It is especially important that we develop a plan in a most timely manner. The production base for American space launch capability is eroding. If we want to maintain a healthy and competitive production base, we must act now.

In any event, the use of ELV's to complement the shuttle would not be a substitute for a viable orbiter fleet. We must have both. We must provide the facilities and spare parts to meet the demanding shuttle schedules. In my view, unless we decide in the future to

end STS flights at the end of the life of the current four orbiters, we must have a continuing orbiter production capability.

This approach should not be seen as a reduction in our commitment to the shuttle, but a commitment to increase the flexibility, the robustness, and the responsiveness of our space launch capability.

Thank you, Mr. Chairman.

I would be happy to answer any questions you may have.

[The prepared statement of Hon. Edward C. Aldridge, Jr., follows:]

DEPARTMENT OF THE AIR FORCE

STATEMENT OF

HONORABLE EDWARD C. ALDRIDGE, JR.

UNDER SECRETARY OF THE AIR FORCE

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

HOUSE OF REPRESENTATIVES

CONCERNING

AIR FORCE ACTIVITIES AND ISSUES

ASSOCIATED WITH

THE SPACE SHUTTLE PROGRAM

FEBRUARY 23, 1984

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

I WELCOME THIS OPPORTUNITY TO ANSWER THE QUESTIONS RAISED IN YOUR LETTER OF JANUARY 16TH, AND TO DISCUSS AIR FORCE SPACE PARTICIPATION IN THE DEVELOPMENT OF THE SPACE TRANSPORTATION SYSTEM. TODAY, IN RESPONSE TO YOUR REQUEST, I WILL JUST BRIEFLY OUTLINE OUR VIEWS ON THE FOLLOWING SUBJECTS:

- ACTIVITIES RELATED TO THE AIR FORCE SPACE COMMAND
- UPDATE ON CURRENT FACILITIES, OPERATIONS AND USER ACCOMMODATIONS AT VANDENBERG AFB
- AIR FORCE PARTICIPATION IN THE CENTAUR UPPER STAGE PROGRAM
- SPACE SHUTTLE OPERATIONAL STATUS
- AIR FORCE REQUIREMENTS RELATED TO A MANNED SPACE STATION
- DEFENSE DEPARTMENT PLAN FOR ASSURED ACCESS TO SPACE

SINCE THE FORMATION OF THE AIR FORCE SPACE COMMAND ON SEPTEMBER 1, 1982 AT COLORADO SPRINGS, ACTIVATION AND TRANSFER ACTIVITIES HAVE CONSISTENTLY BEEN AHEAD OF SCHEDULE. SPACE COMMAND NOW OPERATES AND IS RESPONSIBLE FOR FOUR BASES; 22 SENSOR SITES; AND TWO OPERATIONAL SATELLITE SYSTEMS, THE SATELLITE EARLY WARNING SYSTEM AND THE DEFENSE METEOROLOGICAL SUPPORT SATELLITES. ADDITIONALLY, SPACE

COMMAND HAS BEEN DESIGNATED AS THE OPERATIONAL MANAGER FOR THE FUTURE MILSTAR MILITARY COMMUNICATIONS SPACECRAFT AND THE GLOBAL POSITIONING SATELLITES WITH ITS ASSOCIATED NUCLEAR DETONATION DETECTION SYSTEM. FURTHERMORE, SPACECOM HAS ASSUMED RESPONSIBILITY FOR THE DEFENSE DEPARTMENT'S OPERATIONAL SUPPORT TO NASA'S SPACE SHUTTLE PROGRAM. I AM ALSO PLEASED TO REPORT THAT GROUND-BREAKING FOR THE CONSOLIDATED SPACE OPERATIONS CENTER (CSOC), A KEY ELEMENT FOR SPACE COMMAND'S FUTURE MILITARY SPACE SUPPORT OPERATIONS, TOOK PLACE IN MAY 1983 AND IS PROCEEDING SATISFACTORILY. IN ADDITION TO THE SATELLITE OPERATIONS CENTER REQUIRED TO OPERATE THESE SATELLITES, THERE WILL BE A SHUTTLE OPERATIONS AND PLANNING COMPLEX (SOPC) PORTION OF THE CSOC, WHICH WILL BE USED BY THE DEFENSE DEPARTMENT TO SUPPORT NATIONAL SECURITY SHUTTLE MISSIONS.

WITH REGARD TO ACTIVITIES AT VANDENBERG AIR FORCE BASE, I AM PLEASED TO INFORM THE COMMITTEE THAT THE ACQUISITION OF THE WEST COAST SPACE SHUTTLE LAUNCH FACILITY, IS ALSO PROCEEDING ON SCHEDULE AND SHOULD BE READY TO SUPPORT AN INITIAL LAUNCH CAPABILITY IN OCTOBER 1985. ADMITTEDLY, THE SCHEDULE IS TIGHT, BUT WE ARE WORKING HARD TO MAKE IT. FACILITIES TO SUPPORT THE ORBITER ARE ESSENTIALLY COMPLETE. THE LAUNCH PROCESSING CONSTRUCTION -- SUCH THINGS AS THE LAUNCH CONTROL CENTER, LAUNCH PAD, EXTERNAL TANK PROCESSING AND STORAGE FACILITY, SOLID ROCKET BOOSTER PROCESSING FACILITIES, AND ORBITER CHECKOUT AND MAINTENANCE FACILITIES -- IS

95% COMPLETE. WE ARE SCHEDULED TO BEGIN GROUND SYSTEM TESTS TO CHECK OUT FACILITY EQUIPMENT IN MAY 1984. WE WILL THEN BEGIN FLIGHT HARDWARE COMPATIBILITY TESTS IN NOVEMBER 1984 WITH THE ENTERPRISE (ORBITER-101). THE ACTUAL FLIGHT ORBITER, DISCOVERY (ORBITER-103), WILL ARRIVE IN MAY 1985 FOR THE FIRST VANDENBERG LAUNCH SCHEDULED IN OCTOBER 1985.

VANDENBERG IS DESIGNED TO SUPPORT THREE LAUNCHES IN FY 86 AND FOUR LAUNCHES PER YEAR THEREAFTER. FOR THE FY 86 LAUNCHES, NASA WILL PROCESS AND CHECK OUT THE ORBITERS AND EXTERNAL TANKS AT KENNEDY SPACE CENTER. AFTER FY 86, THOSE FUNCTIONS WILL TRANSFER TO VANDENBERG FOR WEST COAST LAUNCHES.

MR. CHAIRMAN, THE JOINT DOD/NASA CENTAUR PROGRAM IS ALSO PROGRESSING VERY WELL. LAST MAY, SENIOR LEVEL MANAGEMENT PANELS AGREED UPON A BASELINE REQUIREMENTS DOCUMENT. DURING THE SUMMER, KENNEDY SPACE CENTER PRESENTED THEIR STUDIES AND ANALYSIS ON CENTAUR PROCESSING AND OPERATIONS ISSUES; THE GALILEO AND INTERNATIONAL SOLAR POLAR MISSION (ISPM) PHASE II SAFETY REVIEWS WERE COMPLETED; AN AEROSPACE SAFETY ADVISORY PANEL REVIEW WAS FAVORABLY COMPLETED; THE CENTAUR G PROPOSAL WAS RECEIVED AND EVALUATED; AND THE GALILEO AND ISPM MISSION PECULIAR PROGRAM DATA REVIEW WAS

CONCLUDED. IN THE FALL, DESIGN OF THE CENTAUR G-PRIME AVIONICS WAS FINISHED AND MISSION INTEGRATION ACTIVITIES FOR ANOTHER CENTAUR USER WERE INITIATED.

THE OVERALL CENTAUR PROGRAM IS ON SCHEDULE WITH ALL MILESTONES BEING ACHIEVED. THE PROGRAM COSTS ARE TRACKING ESTIMATES VERY WELL, AND EVEN UNDERRUNING IN SOME AREAS. NORMAL DEVELOPMENT PROBLEMS ARE BEING ADDRESSED AND RESOLVED WITHOUT PROGRAMMATIC IMPACTS. ALL PROGRAM INDICATORS TO DATE ARE POSITIVE AND SUPPORT THE OVERALL CONCLUSION THAT THE PROGRAM IS PROCEEDING ACCORDING TO PLAN. ALL IN ALL, WE ARE VERY PLEASED WITH THE WAY THE JOINT CENTAUR PROGRAM IS PROGRESSING.

WITH REGARD TO THE SPACE STATION, I WOULD POINT OUT THAT WE HAVE BEEN WORKING WITH NASA ON THEIR SPACE STATION CONCEPT FOR OVER A YEAR, AS WELL AS PERFORMING INTERNAL AIR FORCE AND DOD STUDIES IN AN ATTEMPT TO IDENTIFY UNIQUE MILITARY REQUIREMENTS. OUR EFFORTS TO DATE HAVE NOT IDENTIFIED MILITARY REQUIREMENTS THAT WOULD BE UNIQUELY SATISFIED OR SIGNIFICANTLY ENHANCED BY A SPACE STATION. NOW THAT THE PRESIDENT HAS CHOSEN TO INITIATE A SPACE STATION PROGRAM, WE WILL CERTAINLY CONTINUE OUR STUDIES AND EXAMINE POTENTIAL CAPABILITIES WHEREIN THE SPACE STATION CAN SATISFY FUTURE REQUIREMENTS. IN ANY EVENT, THE DEFENSE DEPARTMENT HAS APPROPRIATE REPRESENTATION ON THE NASA SPACE STATION

TASK FORCE AND WILL WORK CLOSELY WITH NASA TO ASSURE THAT WE ARE WELL INFORMED ON THE PROGRESS OF THE PROGRAM.

MR. CHAIRMAN, FOR THE REMAINDER OF MY AVAILABLE TIME, I WANT TO ADDRESS THE SUBJECT OF DEFENSE SPACE LAUNCH STRATEGY WHICH INCLUDES OUR VIEWS OF THE SPACE TRANSPORTATION SYSTEM AND WHERE WE WANT TO GO WITH BOTH THE SHUTTLE AND THE USE OF EXPENDABLE LAUNCH VEHICLES OR ELVs.

THE DOD HAS A VALIDATED REQUIREMENT FOR AN ASSURED LAUNCH CAPABILITY UNDER PEACE, CRISIS AND CONFLICT CONDITIONS. ASSURED LAUNCH CAPABILITY IS A FUNCTION OF SATISFYING TWO SPECIFIC REQUIREMENTS -- THE NEED FOR COMPLEMENTARY LAUNCH SYSTEMS TO HEDGE AGAINST UNFORESEEN TECHNICAL AND OPERATIONAL PROBLEMS AND THE NEED FOR A LAUNCH SYSTEM SUITED FOR OPERATIONS IN CRISIS AND CONFLICT SITUATIONS. WHILE DOD POLICY REQUIRES ASSURED ACCESS TO SPACE ACROSS THE SPECTRUM OF CONFLICT, THE ABILITY TO SATISFY THIS REQUIREMENT IS CURRENTLY UNACHIEVABLE IF THE U.S. MAINLAND IS SUBJECTED TO DIRECT ATTACK. THEREFORE, THIS LAUNCH STRATEGY ADDRESSES AN ASSURED LAUNCH CAPABILITY ONLY THROUGH LEVELS OF CONFLICT IN WHICH IT IS POSTULATED THAT THE U.S. HOMELAND IS NOT UNDER DIRECT ATTACK. ADDITIONAL SURVIVABILITY OPTIONS BEYOND AN ASSURED LAUNCH CAPABILITY ARE BEING PURSUED TO ENSURE SUSTAINED OPERATIONS OF CRITICAL SPACE ASSETS AFTER HOMELAND ATTACK.

EXISTING DEFENSE SPACE LAUNCH PLANNING SPECIFIES THAT DOD WILL RELY ON FOUR UNIQUE, MANNED ORBITERS FOR PRIMARY ACCESS TO SPACE FOR ALL NATIONAL SECURITY SPACE SYSTEMS. DOD IS CONCERNED THAT THIS MAY NOT REPRESENT AN ASSURED, FLEXIBLE AND RESPONSIVE ACCESS TO SPACE.

WHILE THE DOD IS FULLY COMMITTED TO THE STS, TOTAL RELIANCE UPON THE STS FOR SOLE ACCESS TO SPACE IN VIEW OF THE TECHNICAL AND OPERATIONAL UNCERTAINTIES COULD REPRESENT AN UNACCEPTABLE NATIONAL SECURITY RISK. DOD BELIEVES THAT A COMPLEMENTARY SYSTEM IS NECESSARY TO PROVIDE HIGH CONFIDENCE OF ACCESS TO SPACE. IN ADDITION, THE LIMITED NUMBER OF UNIQUE, MANNED SHUTTLE VEHICLES RENDER THEM ILL-SUITED AND INAPPROPRIATE FOR USE IN A HIGH RISK ENVIRONMENT.

THE SOLUTION TO THE PROBLEM MUST BE AFFORDABLE AND EFFECTIVE AND YET OFFER A HIGH DEGREE OF REQUIREMENTS SATISFACTION, LOW TECHNICAL RISK, AND REASONABLE SCHEDULE AVAILABILITY. UNMANNED, EXPENDABLE LAUNCH VEHICLES MEET THESE CRITERIA AND COULD SATISFY DOD OPERATIONAL NEEDS FOR A LAUNCH SYSTEM WHICH COMPLEMENTS THE STS AND EXTENDS OUR ABILITY TO CONDUCT LAUNCH OPERATIONS FURTHER INTO THE SPECTRUM OF CONFLICT. THESE SYSTEMS CAN PROVIDE UNIQUE AND ASSURED LAUNCH CAPABILITIES IN PEACE, CRISIS AND CONFLICT LEVELS SHORT OF GENERAL NUCLEAR WAR. THESE VEHICLES ARE DESIGNED TO BE EXPENDABLE AND THE LOSS OF A SINGLE VEHICLE AFFECTS ONLY THAT ONE MISSION AND WOULD NOT DEGRADE FUTURE

COMMON, NATIONAL LAUNCH CAPABILITIES AS WOULD THE LOSS OF A REUSEABLE LAUNCH SYSTEM.

THE PRESIDENT'S POLICY ON THE COMMERCIALIZATION OF EXPENDABLE LAUNCH VEHICLES STATES THAT THE GOALS OF THE U.S. SPACE LAUNCH POLICY ARE TO ENSURE A FLEXIBILE AND ROBUST U.S. LAUNCH POSTURE, TO MAINTAIN SPACE TRANSPORTATION LEADERSHIP, AND TO ENCOURAGE THE U.S. PRIVATE SECTOR DEVELOPMENT OF COMMERCIAL LAUNCH OPERATIONS. CONSISTENT WITH THIS POLICY, THE DOD IS STUDYING THE USE OF COMMERCIALLY PROCURED ELVs TO MEET ITS REQUIREMENTS FOR IMPROVING ITS ASSURED LAUNCH CAPABILITIES. FOR REQUIREMENTS THAT CANNOT BE SATISFIED BY COMMERCIALLY AVAILABLE ELVs, UNIQUE DOD DEVELOPMENTS MAY BE UNDERTAKEN FOR SPECIAL PURPOSE LAUNCH CAPABILITIES.

YOU ALSO ASKED THAT I PROVIDE THE AIR FORCE VIEW ON THE SIZE OF THE ORBITER FLEET. WE NOTE THAT, IN APRIL 1983, THE NATIONAL ACADEMY OF SCIENCES REPORTED THAT IN THE 1990 TIMEFRAME, A FOUR-ORBITER FLEET WITH ALL ORBITERS IN SERVICE WOULD SUPPORT 17 TO 25 FLIGHTS PER YEAR WHICH IS ROUGHLY EQUIVALENT TO NASA'S PROJECTED MISSION MODEL. THE CONCERN WE HAVE IN THE DEFENSE DEPARTMENT IS THAT GIVEN THE NATION'S LONG-TERM RELIANCE ON THE SHUTTLE, AND RECOGNIZING THAT EVERYTHING HAS A FINITE LIFETIME, IT IS IMPERATIVE THAT PLANNING TAKE INTO ACCOUNT HOW TO MAINTAIN THE ROBUSTNESS REQUIRED FOR OUR OVERALL LAUNCH CAPABILITY.

I MUST RE-EMPHASIZE AS I TESTIFIED LAST YEAR THAT A 5TH ORBITER HAS NEVER BEEN AN EXPLICIT REQUIREMENT FROM THE DEFENSE DEPARTMENT PERSPECTIVE SINCE WE HAVE THE OPTION OF EMPLOYING BUMPING RIGHTS FOR NATIONAL SECURITY PRIORITY USE OF THE SYSTEM. IT IS RATHER A QUESTION OF HOW TO MAINTAIN THE LONG-TERM VITALITY OF THE SHUTTLE PROGRAM FOR THE CIVIL, COMMERCIAL AND FOREIGN USERS WHO COMPRISE TWO-THIRDS OF THE SHUTTLE'S MISSION MODEL. OUR EXPERIENCE OF THE PAST YEAR INDICATES THAT, WHILE THE SHUTTLE IS A MOMENTOUS ACHIEVEMENT, IT IS STILL A MOST COMPLEX SYSTEM AND WILL REQUIRE MANY MORE FLIGHTS TO GAIN INSIGHTS INTO ACTUAL COMPONENT PERFORMANCE AND LIFE EXPECTANCY.

IF THINGS WORKED PERFECTLY, THE CURRENT MISSION MODEL AND OUR CURRENT PLANS FOR USE OF THE SHUTTLE WOULD NOT REQUIRE MODIFICATION. WITH OUR PRE-EMPTION PRIORITY, DEFENSE NEEDS COULD BE MET WITH THE CURRENT FLEET OF ORBITERS. HOWEVER, SPACE SYSTEMS DO NOT WORK PERFECTLY. MORE IMPORTANTLY, LAUNCH SCHEDULES CHANGE, AND WE SOMETIMES HAVE UNPREDICTABLE FAILURES OF SPACECRAFT ON ORBIT NECESSITATING QUICK REPLACEMENT. AND SOMETIMES EVEN ON-ORBIT SUCCESSES WHICH EXTEND SATELLITE LIFE HAVE A COMPLICATING IMPACT BECAUSE THEY DELAY THE LAUNCH OF A REPLACEMENT SATELLITE IN UNPREDICTABLE FASHION.

THIS ALL COMES AT A TIME WHEN THE DEFENSE DEPARTMENT IS ACCELERATING AND INCREASING ITS DEPENDENCE ON SPACE SYSTEMS

FOR SEVERAL CRITICAL MISSIONS, FOR WHICH THERE ARE NO NON-SPACE ALTERNATIVES.

FOR THAT REASON, WE MUST HAVE COMPLETE CONFIDENCE THAT WE POSSESS AN ASSURED CAPABILITY TO LAUNCH OUR SYSTEMS WHEN REQUIRED. A TOTAL DEPENDENCE ON THE SHUTTLE MAY NOT PROVIDE THAT ASSURANCE. WE NOTE THAT NOT ALL ORBITERS WILL BE ABLE TO LAUNCH CERTAIN FUTURE DEFENSE PAYLOADS. THE FLEXIBILITY TO INTEGRATE PAYLOADS INTO THE ORBITER IS NOT AS WE ANTICIPATED WHEN WE COMMITTED TO THE SHUTTLE, AND "OPERATIONAL" LAUNCH RATES HAVE NOT YET BEEN DEMONSTRATED. MOST IMPORTANTLY, THE DEFENSE DEPARTMENT HAS CONCLUDED THAT WE NEED "INSURANCE" AGAINST POSSIBLE SHUTTLE FAILURES, FLEET OUTAGES, AND SYSTEM VULNERABILITIES. THIS FUNDAMENTAL CONCERN WOULD EXIST REGARDLESS OF THE SIZE OF THE ORBITER FLEET.

ANOTHER RELATED CONCERN HAS TO DO WITH THE INCREASING COST OF GETTING OUR PAYLOADS INTO ORBIT. OVER THE YEARS WE HAVE OBSERVED A SIGNIFICANT RISE IN THE FRACTION OF THE SPACE SYSTEM COST WHICH IS DEVOTED SOLELY TO LAUNCHING OUR SPACECRAFT. THIS INCREASE HAS UNFORTUNATELY BEEN AT THE EXPENSE OF OUR MISSION PAYLOADS. LOWER LAUNCH COSTS WHICH WOULD PERMIT FUNDS FOR A GREATER ROBUSTNESS IN SPACECRAFT PAYLOADS AND PIPELINES HAVE NOT BEEN DEMONSTRATED. WE ARE, THEREFORE, EVEN MORE DEPENDENT UPON AN ASSURED ON-TIME

LAUNCH CAPABILITY BECAUSE OF OUR LIMITED NUMBER OF SATELLITES.

DOD REMAINS FULLY COMMITTED TO RELIANCE ON THE SHUTTLE AS OUR PRIMARY LAUNCH MEANS, BUT WE ARE ALSO NOW INVESTIGATING THE USE OF A COMPLEMENTARY, BUT SMALL NUMBER OF ELVs. WE WOULD CONTINUE TO PLAN 8-10 MISSIONS A YEAR ON THE SHUTTLE, BUT COULD COMPLEMENT THIS WITH 2 ELV FLIGHTS PER YEAR. SOME 90 PERCENT OF NASA'S MISSION MODEL WOULD REMAIN THE SAME.

- A MAJOR ADVANTAGE TO THIS APPROACH IS THAT THE ELVs WOULD BE USED TO REDUCE OUR "LAUNCH-ON-DEMAND" FLIGHTS ON THE SHUTTLE GOING TO GEOSYNCHRONOUS ORBITS (CENTAUR FLIGHTS).
- THE SHUTTLE WOULD CONTINUE TO BE THE PRIMARY LAUNCH MEANS FOR THOSE DOD MISSIONS IN WHICH MAN PROVIDES A UNIQUE CAPABILITY AND THOSE MISSIONS MORE SUITABLE FOR ROUTINE FLIGHTS WHICH LEND THEMSELVES TO ADVANCE SCHEDULING SUCH AS THE INITIAL LAUNCHES FOR THE GLOBAL POSITIONING SYSTEM AND MILSTAR CONSTELLATIONS.
- THE RESULTING REDUCTION IN DOD LAUNCH-ON-DEMAND FLIGHTS WOULD PERMIT NASA TO SCHEDULE THE SHUTTLE FOR MORE EFFECTIVE AND MORE ROUTINE, MULTIPLE PAYLOAD FLIGHTS. IT WOULD ALSO APPEAR THAT OTHER COMMERCIAL USERS WOULD BE MORE ATTRACTED TO THE

SHUTTLE UNDER THOSE CONDITIONS SINCE IT GREATLY REDUCES THE CHANCE OF DOD PRE-EMPTION.

IT IS ESPECIALLY IMPORTANT THAT WE DEVELOP A PLAN IN THE MOST TIMELY MANNER. THE PRODUCTION BASE FOR AMERICAN SPACE LAUNCH CAPABILITY IS ERODING. IF WE WANT TO MAINTAIN A HEALTHY AND COMPETITIVE PRODUCTION BASE, WE MUST ACT NOW.

IN ANY EVENT, THE USE OF ELVs TO COMPLEMENT THE SHUTTLE WOULD NOT BE A SUBSTITUTE FOR A VIABLE ORBITER FLEET. WE MUST HAVE BOTH AND WE MUST PROVIDE THE FACILITIES AND SPARE PARTS TO MEET THE DEMANDING SHUTTLE SCHEDULES.

A REAL ADVANTAGE OF THIS APPROACH IS THAT ELVs WOULD GIVE US ADDITIONAL FLEXIBILITY AND EXTEND THE LIFE OF THE CURRENT 4-ORBITER FLEET WHILE WE ARE CONSIDERING FOLLOW-ON NATIONAL LAUNCH CAPABILITIES.

THIS APPROACH WOULD NOT BE A REDUCTION IN OUR COMMITMENT TO THE SHUTTLE, BUT A COMMITMENT TO INCREASE THE FLEXIBILITY, RESPONSIVENESS AND ROBUSTNESS OF OUR SPACE LAUNCH CAPABILITY, WHILE HEDGING AGAINST UNFORESEEN TECHNICAL AND OPERATIONAL PROBLEMS IN THE ORBITER FLEET.

THANK YOU, MR. CHAIRMAN; I WILL BE HAPPY TO ANSWER ANY QUESTIONS THE COMMITTEE MIGHT HAVE.

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Mr. VOLKMER. Thank you very much, Secretary Aldridge.

The gentleman from Pennsylvania.

Mr. WALKER. Thank you, Mr. Chairman.

Do you contemplate building any new generation ELV's to take care of the missions that you are——

Mr. ALDRIDGE. Sir, we are—the solution that we're looking at consists of three different vehicles, two of which are variations and modifications of existing ELV's—the Atlas and the Titan. But we've also asked our space division people, who are looking at this, to go explore the possibility of using some shuttle-derived vehicle as a possibility, and we are doing that.

It has the disadvantages of being longer in the development time and much more expensive in the near-term cost, but in order that we would cover the front and have an objective look at this, we did include all three. We have not decided on which of those three we are going to pursue at this point.

Mr. WALKER. If you are determined to use the Atlas and the Titan, is there any chance that you would be able to buy those services from commercial firms that are going to get into that business, rather than do the launching yourselves?

Mr. ALDRIDGE. Yes, sir, that would be the intent—that of the Atlas or the Titan, one of those would be selected for the ELV that we would pursue, we would acquire them in a commercial posture, and that's our intent.

Mr. WALKER. So, in other words, when you talk about your ELV launches, you are, in fact, talking about purchasing that——

Mr. ALDRIDGE. Yes, sir.

Mr. WALKER [continuing]. From the commercial——

Mr. ALDRIDGE. Yes, sir; that's right.

Mr. WALKER [continuing]. Under the regulations now being promulgated——

Mr. ALDRIDGE. Yes, sir.

Mr. WALKER. By the Department of Transportation?

Do you feel that——

Mr. VOLKMER. Would the gentleman yield on that?

Mr. WALKER. I would be glad to yield to the gentleman.

Mr. VOLKMER. This would be a U.S. launch? You'd still launch the vehicle yourself?

Mr. ALDRIDGE. Sir, the plan would be that they could launch it for us as well, and part of the planning would include the procurement and the launch of two per year under our plan.

Mr. VOLKMER. They'd launch it from their own platform?

Mr. ALDRIDGE. No, sir, they'd launch it from a Government range, but they would pay a certain percentage of the cost to launch to us for that purpose.

Mr. VOLKMER. All right. Thank you for yielding.

Mr. WALKER. So, when you talk about Government range, they would either then be launching from Vandenberg or from Kennedy?

Mr. ALDRIDGE. Yes, sir.

Mr. WALKER. Is that correct?

Mr. ALDRIDGE. Yes, sir. Vandenberg—it is not our intent to launch the vehicles that we would buy out of Vandenberg. That

would be—those flights tend to be man-unique, and we'd like to continue that.

The flights we're talking about would be exclusively out of the Eastern test range.

Mr. WALKER. And—which means that essentially then, when you talk about the purchase arrangements, that these companies would be purchasing a launch service from NASA?

Mr. ALDRIDGE. From the Air Force in this particular case.

Mr. WALKER. From the Air Force?

Mr. ALDRIDGE. Yes, sir.

Mr. WALKER. How do you regard the role of the space shuttle? Do you see it as an R&D vehicle or do you see it as a commercially viable system at this point?

Mr. ALDRIDGE. Sir, we look upon it in the Department of Defense as an essential vehicle because we have essentially transitioned all the future DOD payloads to an orbiter launch, and we're looking at it as an operational system for—but, as I've pointed out, we think we need to provide some complementary capability with ELV's to the system.

Mr. WALKER. What's the Air Force investment to date in the shuttle system?

Mr. ALDRIDGE. I could probably provide a specific answer for the record, but I believe it has been on the order of $10 to $12 billion.

Mr. WALKER. I would appreciate having that for the record, if you could provide that at some point.

[The information follows:]

The Air Force investment in the Space shuttle Program through FY 1984 is $3.4 billion. This includes the development of the Vandenberg Lauch and Landing Site, the Inertial Upper Stage, Operational Capability (security and DoD generic airborne and ground support equipment) and the Consolidated Space Operations Center.

Mr. WALKER. Do you foresee a learning curve effect for both the shuttle and the ELV's under the program that you've outlined?

Mr. ALDRIDGE. I believe there is a learning curve effect that will come in from the shuttle because, as we get the launch rate increases in the future, I hope that we can—we will be able to better utilize and understand the problems of the shuttle and how to turn it around and make those operational rates.

I don't believe that you're going to see a learning curve in the ELV's because the ELV's we're talking about, if they are Atlas or Titans, are—basically we've launched hundreds of those already, and I don't anticipate there would be a great learning curve to be obtained there.

Mr. WALKER. Do you see a value in expanding the shuttle fleet to at least a fifth orbiter?

Mr. ALDRIDGE. Sir, I—we in the Department of Defense cannot point to a need in the Defense Department for a fifth orbiter, and I believe my formal statement maintains that, as I testified before this committee last year.

However, from the point of view of a national capability, since DOD only requires one-third of the shuttle rides, we couldn't support as a need for us.

However, it is clear in my mind that unless we want to continue—unless we would decide right in the near future to terminate the shuttle flights when they reach the end of their life, we need

some kind of a continuing orbiter production capability. When that occurs is a subject of national needs, not DOD needs.

Mr. WALKER. Would it cause DOD problems if we were to, for instance, reach out to the international community to try to help us finance a fifth orbiter?

Mr. ALDRIDGE. Not so long as we can maintain the security arrangements that we currently have on the four that we have, and there are not any unique requirements that this international community may put on that orbiter, like for their exclusive use, and so forth.

Mr. WALKER. Based upon your previous answer, would the Air Force be willing to work with NASA at this point to develop a new generation of shuttle—in other words, move us from the DC-1 status to more like a DC-3 status of orbiter?

Mr. ALDRIDGE. What we have agreed with NASA to do—as a matter of fact, the 1985 budget that we've asked for, for this plan of $10 million—$2 million of it will be looking for a heavy lift vehicle for the future. We anticipate that our payloads will get larger than the 15- by 60-foot payload bay and get heavier as we get—look for future requirements, and we believe that a heavy lift vehicle in the midnineties is a definite requirement. That, I understand, between ourselves and NASA is not an issue. We all agree that that's where we should be going for the future.

Mr. WALKER. Do you visualize that as being a manned vehicle or an unmanned vehicle?

Mr. ALDRIDGE. Really undefined at this point. The only part of it we feel is appropriate is some shuttle-derived components out of the current shuttle—the solid rockets, the main engines, or even the external tank. And exactly how those configurations are put together is still subject to study.

Mr. WALKER. Thank you, Mr. Chairman.

Mr. VOLKMER. The Chair will now recognize the gentleman from Florida, Mr. MacKay.

Mr. MACKAY. Mr. Aldridge, this is my first year on this committee, so I may ask some questions that are very basic for you.

Is the Air Force effort to develop the expendable launch capability—is that a new dimension or has that been your plan all along?

Mr. ALDRIDGE. No, sir. Back when—I believe 1978 was the most recent MOA between the Department of Defense and NASA—a decision was made at that time with five orbiters that it would be—the orbiter would be the exclusive system to place DOD payloads in orbit. It would be totally dependent on the orbiter.

However, while the system was being developed, there was a policy established that we would back up that schedule for the orbiter with ELV's for 2 years out of the Kennedy, the Eastern test range, and 1 year out of Vandenberg. So that while the shuttle was in this development period, and until it received an operational capability, we would back it up with ELV's.

That policy has now gotten to the point where we're looking for the future and we're looking at essentially a change in the conditions under which we signed up to that original agreement, and that's our concern. We're seeing now more—the cost numbers are different than we signed up to; the operational flexibility that we anticipated in the early years is different. I think we've thought

through those kinds of conditions under which we are totally dependent upon the shuttle and consider those now to be inappropriate.

So this is a new decision to supplement and complement the orbiter, certainly not to substitute for it. The issue there is that we feel now that having the orbiter as the only way for the U.S. Government and the Department of Defense to get to space is really inappropriate at this particular point.

So this plan I've outlined today is, in fact, new.

Mr. MACKAY. Does it reflect a disappointment or a lack of satisfaction of expectations on the part of the shuttle or does it reflect a different understanding of the risks involved?

I noticed in your testimony you talked about the possibility of the United States being under attack and the need to have launch capabilities elsewhere.

What part of that was not foreseeable in 1978?

Mr. ALDRIDGE. I think several things, no one that you could point to.

We did anticipate in the midseventies, when we signed up, five orbiters, all of which were fully performance capable. That was advertised and anticipated, fully logistically supported, with turnaround times that were quite reasonable to support any future mission model and at costs that were significantly lower than they are today, which allowed us to consider the fact, because of the economics, to put the money—rather than in launchers—into the payloads, which certainly is the right direction to go. We could build a robustness into our spacecraft line.

There have been some disappointments with regard to those factors. However, I think most of it has been a reality that the difficulties of integrated payloads into the orbiter and the experience level we are now seeing are giving us a little more reality about how does one get to space and how does one make sure that you can meet your requirements. I think that is a difference.

The other difference is at the timeframe we—in discussing the Department of Defense needs and the view of how we're going to use space, we really designed our spacecraft for a peacetime environment. We really didn't consider them a wartime support role. That has, in fact, changed. We are now seeing the current national space policy the President put out in July 1982 clearly focuses a more capable, more survivable, more enduring space system to better support the military commander, because now we're seeing the value that space can, in fact, provide to the military commanders to multiply the effectiveness of our forces. I think that reality is accelerating, and was not fully anticipated at the time we signed up to the orbiter.

All those factors have said it appears to us that we need a more robust launch capability, because the number of satellites that we are buying is really not—we're being pretty prudent and there's not a great deal of those, so we have to make sure that the satellites we do buy have direct access to space right away, as well as the need for a more robust and survivable system across the spectrum of conflict, certainly not to the point where we can survive an attack directly on the United States, but up through crisis.

All of those factors have given us pause to rethink the original decision and, as a result, we feel that this new plan is a result of providing that additional robustness in our launch capability.

Mr. MACKAY. I'm not asking this question to make any point or to be argumentative, but from NASA's point of view some of the delay and cost was necessary, as I understand it, for redesign to meet your requirements?

Mr. ALDRIDGE. To some extent, that is correct, but when the Department of Defense signed up to the shuttle, there was an advertised performance capability of size and weight to various kinds of orbits. We then initiated a plan to reconfigure all of the satellite systems to meet that performance requirement. The shuttle performance requirement was never—never quite got there. And these new things we hear about, the filament wound case and the higher performance main engines, are a result of direction from NASA to get up to the originally advertised performance, which had already been there because of our satellites.

Our satellites have not grown in weight. The performance capability shuttle has not achieved its goal.

Mr. MACKAY. The shift you mentioned—let me start over.

Is the change in the Air Force emphasis a desire to be prepared for the star wars high frontier dimension of where we're headed?

Mr. ALDRIDGE. No, sir. We would think that that launch capability would be more appropriate for a heavy lift vehicle in the midnineties that would use components derived from the current, existing shuttle, and that we're—NASA and ourselves are in complete convergence on that issue, that there needs to be some heavy lift vehicle for midnineties. And that's the kind of capability we need for the new strategic defense initiative concepts.

Mr. MACKAY. So that's—any shift in your position is not related to a shift in the view of a strategic warfare, outerspace capabilities and the Air Force's role in that?

Mr. ALDRIDGE. No, sir. The payloads that we would be talking about in this plan through the midnineties have already been designed, and it's a matter of making sure we could launch them when we need them.

Mr. MACKAY. Does the shift carry with it any risk that the Air Force will decide on cost parameters to use ELV's instead of the shuttle, say for loads that are already in the shuttle's future scheduling?

Mr. ALDRIDGE. Let me address it—it is not our intent right, at this point in time, to fly more than two launches per year off of that ELV. However, because of that ELV production, if for some reason we ran into difficulty in scheduling an orbiter or if there was some problem that we damaged one and one had to be taken out of the production line, that opportunity to fly would exist with this ELV production capacity. That opportunity would exist for us to do that in an emergency, but it's not our intent to do that under this plan.

Mr. MACKAY. Did you have any knowledge, based on the performance of the shuttles thus far, that leads you to believe that you need a backup?

Mr. ALDRIDGE. No, sir. It's just the question that our entire capability to get to space is based upon four vehicles, and the uncertain-

ties that exist with four vehicles, two of which can launch DOD payloads that we're talking about with Centaur. And it's that uncertainty and concern that says it seems to us in the Department of Defense, whose task is to make sure for national security purposes, and essential national security purposes, we have the ability to get to space when we need to—and that concern has said it seems to us to be prudent to back that capability up with an ELV which can launch without having the—when we need to and not be dependent upon other people.

See, the problem we have is the concern over launch-on-demand. When we need to replace a satellite in orbit for DOD purposes, it needs to be replaced as soon as we possibly can get there. Now the problem that creates is that puts pressure on the Department—on the shuttle program to be prepared to launch on that date. And, unfortunately, we have to schedule a shuttle pretty far in advance. And we, therefore, have to make a prediction of when that satellite may fail. And, unfortunately, we've never predicted that correctly. It's either been before—but more times than not it has been after; it lasts longer. So while we manifest a flight for a particular day, assuming failure, and it doesn't fail, we can't sit there and wait for the failure to occur, because that shuttle has to go fly another mission 30 or 60 days after that. So we're sitting here with a dilemma of whether to pull the payload out of the shuttle bay or to go ahead and launch and kill a live satellite and one that's working perfectly, and the latter is very, very tough for us to do.

The thing we think the ELV will do for us is we'll put those payloads which are the most critical launch-on-demand on the ELV, and it could launch any time it wants to, and we'll take the pressure off the shuttle to fly those kinds of payloads. Therefore, the shuttle can now be scheduled in a more realistic way, a more routine way, for those payloads which can fly in that regard.

But it is not our intent to take away all of the shuttle flights that we—we're still going to fly 8 to 10 shuttle flights a year for those payloads in which, in fact, man is unique or those which can be more routinely scheduled.

Mr. MACKAY. This is another question not intended as an editorial but for facts. Your research budget—how does it compare with NASA's, your space research budget, DOD's space research?

Mr. ALDRIDGE. I don't have the figures of how we break it out between R&D and procurement and operations, but right now I believe the DOD budget for space is about $9 billion, and that compares to roughly $7 billion for NASA.

Now, of course, that includes the Vandenberg construction, and there would be, as that fades away and operations come in, it will change, but it's around about $9 billion a year.

Mr. MACKAY. So at this point NASA is not our major space effort?

Mr. ALDRIDGE. No, sir. The Department of Defense is.

Mr. MACKAY. I guess the last thing is, one option you would have would be to continue to support the fifth orbiter. And your withdrawal of support for the fifth orbiter, in effect, prejudices the ability—it's almost like you're putting NASA in a catch-22. You're saying, "We've decided we don't want a fifth orbiter, and, P.S.,

we've decided we've got to develop a backup system because with only four orbiters there's not enough margin for error."

Mr. ALDRIDGE. Let me address that. The view that we place is that the number of orbiters doesn't change our view about the value of a complementary system. So the number of orbiters is not the issue there.

The concern is that we in DOD can't point to a fifth orbiter as a definite requirement to meet our needs, because we only fly a third of the missions, not the rest or the two-thirds. The fifth orbiter issue should be focused on the national need, the entire mission model. Does the country need a fifth orbiter?

And my view of that is it seems like it's logical that unless we're going to stop flying orbiters at the fourth orbiter, we need a fourth and a fifth and a sixth and a seventh. We need a continuing production capability.

But the demands on that production should be based upon the national need, not just the Department of Defense need, looking at the entire model and when those productions should start, based upon the total mission need. That's our position.

Mr. MACKAY. It would seem to me, Mr. Chairman, that in light of the contention that this committee has heard before that the rest of the space, the civilian space research program got scavenged in order to keep the shuttle on course, that this committee ought to think very carefully about trying to separate the civilian research from the military research.

I'm not being critical. There are legitimate times when circumstances change and the military needs change. Now suddenly we have put the rest of the space research program maybe a decade back trying to get the shuttle in gear, and find that the military basically sees good reasons now why the shuttle would not be a crucial thing.

Mr. ALDRIDGE. Sir, can I address that? We are not saying that the shuttle is not crucial. We are absolutely committed and require the viability of the shuttle fleet. There is no way that this plan we're talking about backs us away from the commitment to the shuttle. We are only talking about 2 flights per year versus 8 to 10 on the shuttle. We're absolutely committed to the shuttle and absolutely supportive.

The national security requirements dictate that we maintain a viable shuttle fleet. There is no doubt about that.

Mr. MACKAY. From the standpoint of a person who is concerned about civilian space research, however, we have taken a major part of that program and used it, in effect, to support the military needs for a number of years, thinking that that was satisfying a military need, and we now find that it is not.

Mr. ALDRIDGE. No, sir. The shuttle is absolutely satisfying our need. There are unique national security payloads that can be flown only upon the shuttle.

And I don't—the shuttle is really supporting a national need of which the military is one-third of it in this particular instance.

Mr. MACKAY. Thank you.

Mr. VOLKMER. The Chair now recognizes the gentleman from Virginia, Mr. Bateman.

Mr. BATEMAN. Thank you, Mr. Chairman.

Mr. Secretary, is the demand or the need on the part of the Department of Defense for putting payloads into space trending upward over the last 5 years, or projected to do so for the next 5 years, or is it leveling off or falling?

Mr. ALDRIDGE. I would believe that the number of launches per year is probably leveling off. However, the dependence upon those vehicles we're launching has accelerated, in the sense that we're finding things and committing more of our national security interest in space more so than we anticipated 10 years ago. And the value that we obtain from space is accelerating, to the point where we're seeing the use of space to multiply the effectiveness of the forces is increasing our ability to support our national security interest is, in fact, increasing. The value of each satellite is increasing while the number of satellites we're launching is staying about the same.

Mr. BATEMAN. And you don't anticipate that there is going to be an increase in the number of satellites or other payloads that you will need in space?

Mr. ALDRIDGE. Well, that would be speculating, and maybe sometime in the future as we would move toward this new strategic defense initiative there may be in the midnineties the need to do that, but right now I don't anticipate that until the year 2000 that we'll see any major shifts in the rate of launch of our national security or space programs.

Mr. BATEMAN. If there were a fifth orbiter, I take it it would have some utilization by the Department of Defense?

Mr. ALDRIDGE. Yes, sir. I think the fleet that we would draw from to meet our demands would be drawn from the fleet of five rather than from the fleet of four.

Mr. BATEMAN. Well, if there were a fifth, you would use that. If there's not a fifth, your requirements remaining the same, you'd have to use something else?

Mr. ALDRIDGE. Yes, sir.

Mr. BATEMAN. Do I read it that there's a preference to use something else because it gives you a multiple choice of launching capabilities?

Mr. ALDRIDGE. That's right; yes, sir. It's not depending on a single system to get to space. We now have a more—we would have a more robust capability across the——

Mr. BATEMAN. Robust?

Mr. ALDRIDGE. Robust—it's a good word. [Laughter.]

Mr. BATEMAN. Well, it would give you a choice. Robustness doesn't really seem to have the same connotation, but that's purely semantic.

Let me ask you this: pricing policies as between the Department of Defense and NASA for your participation in the shuttle, do you look upon existing agreements, formulas, or however the prices are arrived at, as being equitable or not?

Mr. ALDRIDGE. Sir, we look upon the principle by which we signed up to the pricing policy as being equitable, and the equitability of that, if that's the right word, is one based upon the fact that we will pay for the cost to launch, but that the country ought to look upon the shuttle program and the base on that as a national asset, and it really—the taxpayer pays for that.

And now what does it cost us to launch each vehicle, the expendables and the refurbishment, and that kind of thing? And the principles by which we've reached agreement are equitable, and we agree with that.

Mr. BATEMAN. In other words, you don't feel like you're being penalized by more being attributed of the cost to you than should be borne?

Mr. ALDRIDGE. No, sir. We——

Mr. BATEMAN. The taxpayers probably don't care because the dollars are the same.

Mr. ALDRIDGE. Yes, sir.

Mr. BATEMAN. They are attributable to X or to Y.

Mr. ALDRIDGE. The principles by which we entered the program are the same today as they were in 1978, that we would construct the facility at Vandenberg; we would develop the inertial upper stage for launching; and we would commit all of our satellites to the shuttle capability. That cost is about a third of the total cost of the shuttle fleet that NASA has borne, and yet we fly about a third—30 percent—of the number of flights. We feel that the total cost is equitable, and then the cost per flight—as a matter of fact, the price that we've signed up to in 1975 dollars is $29.8 million per flight. That's exactly what Jim Beggs asked us to sign up to, and we agreed with it.

Mr. BATEMAN. That's all the questions I have, Mr. Chairman.

Mr. VOLKMER. The Chair recognizes the gentleman from California, Mr. Dymally.

Mr. DYMALLY. Thank you very much, Mr. Chairman.

Mr. Secretary, last year the Air Force testified before the subcommittee in strong support of a fifth orbiter. This year both you and NASA are somewhat lukewarm. I get the impression that I am not at least getting the real story, that someone higher than you and I made a decision and both you and NASA are reluctant participants. You say, in effect, "We don't want a fifth orbiter" because somebody made a decision, whether it be the White House—and I don't get a good feel. I don't think I'm getting the real answer.

Would you give me some reassurance that this is a decision that you are enthusiastically supporting? What happened between the Christmas holiday and last year when you testified? Was the recess damaging for the fifth orbiter?

Mr. ALDRIDGE. Well, let me address—I don't believe, from our perspective, the position that we took last year is different than the position we're taking this year. We're saying that there is a need to continue the production capacity for orbiters, unless we want to throw the four away we've got at the end of their lifetime and go to something else. That, to me, has to be logical and defendable.

However, I also said last year the Department of Defense could not itself support the fifth orbiter. It had to be based upon a national model defended from a NASA perspective, which has the responsibility of launching the shuttle.

And I believe from their point of view at that point last year the administration did not support the need for a fifth orbiter under the apparent conditions that we look for for the mission model. And, of course, this year NASA did not include the fifth orbiter in

their budget submission. I believe that was testified to yesterday for this particular budget.

I guess the issue is, when do you need the fifth orbiter and how does one go about providing the production capacity to get there? That's an issue that has to be based on a national need.

Mr. DYMALLY. Well, I understand that, and I know this is not a fair question, and you don't have to respond. I just get the impression that somebody higher up than you and I said, "Let's slow down on this request."

If the chairman of this committee told me not to ask you a question, I sure as heck am not going to ask it, because I want him to give me some time to ask you some other questions.

And I get the impression that somebody said, "Hey, let's cancel the fifth orbiter and let's do the space launch."

Anyhow, you don't have to respond to that, but I don't leave these hearings with a good feeling that this was a sound side effect, sound economic, sound security decision. I am still uneasy, and perhaps I could be made to feel better about it in some subsequent communication with the Air Force or NASA——

Mr. ALDRIDGE. Well, the——

Mr. DYMALLY [continuing]. So that I could leave this committee feeling good about it.

Mr. ALDRIDGE. Yes, sir.

Last year the President elected not to provide the funds for the fifth orbiter, but elected to provide for the spare parts necessary to maintain the viability of the four-orbiter fleet and to hold the option open for the production for the fifth orbiter, and that was pretty straightforward. It is not a decision of whether or not the fifth orbiter, but not in that fiscal year.

Mr. DYMALLY. Let's shift gears a little. Can you tell us how enthusiastic the various aerospace companies are to take over as a commercial venture the building of the expendable launch vehicles?

Mr. ALDRIDGE. Let me give you my interpretation of their enthusiasm. It would probably be better to ask them themselves.

They are providing the studies necessary—I'm sorry, maybe I misunderstood the question. You're talking about taking over the launching of the shuttle?

Mr. DYMALLY. Yes.

Mr. ALDRIDGE. Yes, sir. I was thinking of the ELV.

No, the shuttle would—as a matter of fact, the shuttle processing contract that was let, in which the Air Force joined with NASA, is essentially commercialization of the launch capability.

Mr. DYMALLY. My question is, do you think we have enough enthusiasm in the private sector? Is there a big enough market other than DOD in the private sector to proceed with this project?

Mr. ALDRIDGE. The project of the Shuttle?

Mr. DYMALLY. Yes.

Mr. ALDRIDGE. I believe so. I'm not sure I've got your question fully in mind here, but are you speaking of taking over the launch operations of the shuttle in a commercial——

Mr. DYMALLY. Yes.

Mr. ALDRIDGE [continuing]. Venture? I don't see a lot of enthusiasm to do that. In fact, I would be concerned about the complete

commercialization of having to provide a space transportation corporation in which we would have to go to the commercial firm to buy flights. My concern from the Department of Defense is how do we maintain the security of that particular effort, and I believe it would be better, in my view, to keep a small organization within the Government monitoring that, so that they could provide the necessary guidance and policy and licensing to carry that out; then have the basic work done in launch facilities, which is what we're proceeding to do with the shuttle processing contract.

Mr. DYMALLY. We've received testimony that the cost of these launches is increasing. What are the factors that are causing the increase in the cost?

Mr. ALDRIDGE. I don't believe the costs are increasing. I think we've just got a better handle on what it actually costs to launch, and that the real costs are much higher than that which we anticipated. We would hope that the launch cost would actually start decreasing with time and to come down to something which is more reasonable, but that's— it's just like the learning curve that currently exists, that the number of flights of the orbiter are very small and we've had to prorate a very large overhead over a small number of flights, so the actual cost per launch is very, very high, but we would hope that that would come down.

It is true that we are charging a much lower cost than our actual cost to launch the shuttle.

Mr. DYMALLY. Thank you very much, Mr. Chairman.

Mr. VOLKMER. Thank you.

The gentleman from Washington, Mr. Chandler.

Mr. CHANDLER. I have no questions, Mr. Chairman.

Mr. VOLKMER. I have several questions, Mr. Secretary.

One is I understand that Secretary Weinberger has basically signed off on this strategy as of February 7?

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. This means that we will have an ongoing program. How much are you requesting in 1985 funds?

Mr. ALDRIDGE. $10 million.

Mr. VOLKMER. $10 million.

Mr. ALDRIDGE. Yes, sir. That is broken into two parts. Eight million would be studying the concept that we select for the commercial ELV. We've got to make a decision on which one of those it will be.

Mr. VOLKMER. We're talking about an Atlas Centaur or a Titan Centaur or what?

Mr. ALDRIDGE. Yes, sir. As I pointed out before, we're studying three options—Atlas Centaur, Titan Centaur, and a shuttle-derived vehicle.

Mr. VOLKMER. That's for more heavy lift?

Mr. ALDRIDGE. No, sir. They all have the same lift capacity, which is the current shuttle payload.

Mr. VOLKMER. All right.

Mr. ALDRIDGE. And we will decide which one of those is the correct solution this summer, so that in 1985—on October 1, 1985, October 1, 1984, when the fiscal 1985 budget would theoretically start—we have $10 million identified, $8 million of which would be to study the payload integration of that vehicles onto our satellites

to make sure that we've got a compatibility between our satellites and that particular vehicle. The remaining $2 million would be to continue to study a shuttle-derived, heavy lift vehicle for the mid-nineties.

Mr. VOLKMER. And what's the total payload weight of that heavy lift that you're looking at?

Mr. ALDRIDGE. A variety of different concepts, but in the order of 150,000 pounds to low earth orbit.

Mr. VOLKMER. All right. And at the present time are you considering the use of the ELV's for geosynchronous?

Mr. ALDRIDGE. Yes, sir. The plan would be that we would—if we proceed down this plan, starting in 1985, we would fly two flights per year out of the eastern test range to geosynchronous orbit, starting in 1988 through about 1992, is our plan. Hopefully, after the end of this particular plan we would have some capability for a heavy lift vehicle.

Mr. VOLKMER. You've proposed to first use them in 1988?

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. And no more than two a year?

Mr. ALDRIDGE. That's our plan, two a year.

Mr. VOLKMER. That's what concerns me. I can tell you why.

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. Because last year you had no plan to use ELV's at all, and the year before, and the year before. The question is, next year are you going to decide that, no, we should go to four or six, and pretty soon six or eight, and let's go ELV's all the way, and what happens to the shuttle manifest and the shuttle cost and the operation?

Mr. ALDRIDGE. Let me address why I don't believe we'll ever get to all ELV's back in the Department of Defense. We have designed some of our payloads for launch and recovery. That takes a manned system. Other payloads are smaller, such as the GPS, the positioning satellite system, Navstar. It doesn't take up the entire shuttle bay. It only takes up a small percentage of it. We get a very economical ride off the shuttle with those payloads that an expendable launch vehicle for the initialization of the constellation would be very expensive to do that. So we get a very cheap ride in that sense. That's economic sense.

The other payloads do not necessarily require us to launch on demand and they can be scheduled in a much more realistic way. I believe we would continue to support to have two systems rather than having one. We'd be back, roughly, in the same place we were talking about before of having only one type of vehicle to get us into space.

But I'm speculating because, as I am sitting here today, it is not our plan to go to more than two per year unless we run into a national emergency in which we have to grab an ELV off the production line for emergency purposes. Who may be sitting in this chair 4 years from now may have a different view, but that's not our intent at this time.

Mr. VOLKMER. Now in the development of the ELV to equalize the shuttle payload capacity, is that going to be borne completely by DOD?

Mr. ALDRIDGE. No, sir, the plan would be that——

Mr. VOLKMER. Why don't you pick one of these three?

Mr. ALDRIDGE. OK. Let's make the assumption that we pick—I hate to pick one because there's somebody in the back of the room that's going to be mad. [Laughter.]

Mr. VOLKMER. Just say in the event you do "A;" use the letter "A."

Mr. ALDRIDGE. In any event, we believe that there is an up front research and development cost to bring the existing ELV's up to the payload capacity and size that the shuttle has, which is what we were designing our payloads to fit.

That up front R&D cost we would permit to be prorated over the number of vehicles we buy in the commercial venture; 10 vehicles—we have allowed it to be prorated over those 10 vehicles.

So we would not pay the up front cost. That would be a commercial venture by the firm to do that development, and then the price they charge us to fly—we would pay them a certain amount of money and anticipate that that R&D would be prorated.

Mr. VOLKMER. Do you anticipate that the total cost of an ELV would exceed the shuttle rate in that same period of 1988 to 1992?

Mr. ALDRIDGE. It depends upon the pricing policy after the 1988 period. We have signed up to $29.8 million per flight in 1975 dollars up through 1988. If NASA continues that rate, the price that we will pay for a shuttle with a Centaur for the geosynchronous orbit will be less than we would pay for an ELV. If, however, we're forced, as OMB has indicated, to a full cost recovery policy after 1988, the cost of the shuttle plus the Centaur will be more expensive than an ELV with Centaur.

Mr. VOLKMER. And we're talking about a body of 10, then, over a period——

Mr. ALDRIDGE. And launch two per year, yes, sir.

Mr. VOLKMER. And those would be guaranteed by—that would be firm?

Mr. ALDRIDGE. Yes, sir, that would be the plan, that we would buy that many, so that the production capacity of the contractors would be—they could go and invest their capital in providing that production capacity.

Mr. VOLKMER. And, as I understand your testimony in reviewing it, and listening to you today, it appears to me that DOD's major concern with the shuttle has to do with the possibility of a war, something happening there; is that right? Is that one of the concerns?

Mr. ALDRIDGE. I don't think that is one of the concerns. I don't believe—it's not war in regard to the attacking of the U.S. homeland, but crisis conditions where, in fact, one might be concerned by launching a manned system; the dependence upon four vehicles, again only two of which can launch our payloads——

Mr. VOLKMER. Which two are you saying are the only——

Mr. ALDRIDGE. 099 and 104 will be Centaur compatible. And the concern that——

Mr. VOLKMER. That's those types of payloads?

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. But the other type of payloads we can——

Mr. ALDRIDGE. The other type—it so happens there are two others, one——

Mr. VOLKMER. You said that only those two would be able to carry DOD payloads. That's not quite accurate.

Mr. ALDRIDGE. One——

Mr. VOLKMER. Certain payloads?

Mr. ALDRIDGE. Certain payloads; that's right.

Mr. VOLKMER. Heavier payloads?

Mr. ALDRIDGE. The heavy ones, yes, sir.

And the—it's the concern that our total access to space is dependent upon, right now, those four satellites, those four orbiters, and the concerns about what would happen if we break one or if there was a concern over the grounding of a particular, for some reason, solid rocket motor, or whatever—do we want to be dependent from the point of view of, I as a user, of putting payloads in orbit—do I want to—am I comfortable dependent upon those four vehicles to get to space for the country?

Mr. VOLKMER. But you knew that 2 years ago, 3 years ago, and last year?

Mr. ALDRIDGE. Yes, sir, we knew that. We didn't know it to the degree that we currently know it until about a year or so ago.

Mr. VOLKMER. Are you telling me now that the shuttle is less reliable today than it was 2 years ago?

Mr. ALDRIDGE. No, sir, it's not——

Mr. VOLKMER. One year ago?

Mr. ALDRIDGE. No, sir, it's the concerns about the turnaround, the actual cost that we're talking about to launch, the learning process that we've gone through in integrating our payloads once we get up into the launch rate, the understanding of the actual flexibility that exists in the shuttle. All of these are new factors that really have only come to light in the last year or two, as we've really gotten into the shuttle launch rate. It was not anticipated——

Mr. VOLKMER. But the turnaround time is coming down?

Mr. ALDRIDGE. It is coming down, yes, sir, and——

Mr. VOLKMER. And the costs are coming down? General Abrahamson testified to it yesterday.

Mr. ALDRIDGE. The actual cost to launch may be coming down, but we don't anticipate that the cost—the charge that will exist after 1988 is going to be below what we're currently charged.

Mr. VOLKMER. And even if it's not, it's still going to be less than ELV?

Mr. ALDRIDGE. No, sir, it depends upon what is the price. Right now we don't anticipate that the shuttle is any cheaper than an ELV, so the cost to launch it——

Mr. VOLKMER. But you don't know today what that ELV is going to cost you?

Mr. ALDRIDGE. We have a pretty good indication because we have launched hundreds of them. The issue is what is the nonrecurring cost to develop that ELV to make it compatible with the shuttle. That's the only uncertainty, and that is very small.

Mr. VOLKMER. Do you see any implications, then, in the view of foreign users of the shuttle and the commercial users of the shuttle of DOD's apparent lack of support for the shuttle now?

Mr. ALDRIDGE. Sir, if you looked at our mission model, you would find no lack of support for the shuttle. We are still absolutely de-

pendent on the shuttle. Our concern is making sure we get that timely launch.

My view of the world is that the foreign countries when looking—now that the United States has a viable ELV, they would very much consider the competition of that ELV with Ariane and not with the shuttle.

Mr. MACKAY. Mr. Chairman.?

Mr. VOLKMER. Just let me finish.

Now, as I understand this, the program is definite now. There's not just a question on the ELV's?

Mr. ALDRIDGE. I'm sorry?

Mr. VOLKMER. It's a definite defined program as far as ongoing and going forward with it? It's not one just investigating the——

Mr. ALDRIDGE. No, sir, let me address it. We are studying, with just Air Force study funds, what might be a viable ELV based upon Atlas, Titan, and shuttle-derived. The decision to proceed with this plan will be—is—included in the Defense Department request for budget in fiscal year 1985, the $10 million that are included in the Air Force R&D line to study this issue. That requires congressional approval for appropriating of those funds. And without that appropriation and the agreement with that plan, we cannot go forward with such a program.

It is a recommendation, a study in 1984. We will decide which is the viable ELV this summer, so that we can initiate that contract beginning in fiscal year 1985 with the $8 million that we have available—that we would have available if Congress appropriates the funds.

Mr. VOLKMER. Now we've had to have two DOD launches cancelled, one last year and one this year so far. But that's basically because of the IUS; is that not correct?

Mr. ALDRIDGE. Sir, it's difficult for me to—we normally do not comment about what a DOD payload is or what its upper stage is.

Mr. VOLKMER. All right.

Mr. ALDRIDGE. And——

Mr. VOLKMER. Then let me ask you this: Where are we on the IUS?

Mr. ALDRIDGE. We're studying the problem and, hopefully, we will be in a position that, if we do launch—if we can get back on track, we can launch an IUS before the end of this year.

Mr. VOLKMER. You'll be able to do it better with ELV's than the IUS, then?

Mr. ALDRIDGE. That's not a—IUS is not a competitor with ELV's.

Mr. VOLKMER. I agree with that.

Mr. ALDRIDGE. What we're planning to do with an ELV is to fly an ELV-Centaur.

Mr. VOLKMER. OK.

Mr. ALDRIDGE. Not an ELV-IUS.

Mr. VOLKMER. And you're satisfied, too, with the progress in the Centaur?

Mr. ALDRIDGE. Absolutely; it is a model program, a joint program between the two agencies that is working very, very well.

Mr. VOLKMER. Now, as I understand, DOD basically has no real position on the space station other than at this time you see no defense needs for a space——

Mr. ALDRIDGE. We have not identified any. We're going to continue to look at it, now that the President has made the decision to proceed, but I don't anticipate any change in that position as we continue to study.

Mr. VOLKMER. One of the problems that I see that may arise—and correct me if I am wrong—that as the shuttle progressed, and was brought out by the gentleman from Florida, defense needs were defined as far as the shuttle, that changes had to be made. If we proceed with the space station concept and get into hardware in 1987, and then Defense by then decides that there are sufficient things, and changes should be made, do you think—shouldn't the Department of Defense then be agreeable to sharing part of the cost for all of those changes?

Mr. ALDRIDGE. It's a slightly different issue. The shuttle, the DOD needs were identified from the very beginning, and that was designed into the system from the start. At this point in time we don't have any requirements that we've identified, and I would think that if we did find some, we would be willing to pay our fair share to modify or to augment the space station in the future.

But there is no—again, we have not identified those right now.

Mr. VOLKMER. The need—I am going to get back to the 10 ELV's. The need for those is, then, basically as backup to the shuttle. They'll be used two a year. Have you identified the missions yet for those two?

Mr. ALDRIDGE. No, sir, not specifically, but the concept is we would pick those missions which are the most critical in terms of launch-on-demand, and we have several that we're looking at, both from the standpoint of making sure that those are the most critical and also insuring that we are not getting—have to pay a very, very high price to modify those satellites to be dual compatible, to fly either on the orbiter or on the ELV.

Mr. VOLKMER. As I look at the manifest for the shuttle for 1988, I see there is 1—let's see, I think they add so far up to about 18 on there, maybe 19 now, but they had 1 spot for DOD that has not been—in other words, it's reserved but not mission-designated yet. Undoubtedly, that would probably be scrapped then?

Mr. ALDRIDGE. Possibility. I'm not sure which that mission is. We normally don't just put a spare. We normally identify a manifest or identify a launch possibility based upon a mean mission duration for the satellites, anticipating replacement. I'd have to go and see what that mission model looks like, but the intent would be in 1988—and I believe we have in the Department of Defense about eight—it seems like it's eight payloads planned to launch. We would launch two of those eight on an ELV.

Mr. VOLKMER. And those would both be from KSC or from Canaveral?

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. On the question of the commercialization of the ELV's and the use of Government facilities, you've testified here if you go with this program, whoever the commercial supplier is will be supplying launch, also.

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. There will be a reimbursement on that, of course?

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. Is that reimbursement going to be based on additive costs or cost recovery or——

Mr. ALDRIDGE. It's—the definition of what is additive and direct is very ambiguous, as I've gone through this.

What we have agreed to do—the principle by which we would permit this to happen is that we would charge the commercial user the same rate as we would charge another Government agency. That, it so happens, is called direct cost, but in my view it's additive cost. It's the cost that a person who, at the range may spend an hour working on that launch; we would charge the commercial user that hour of his time. We would not charge all the overhead and retirement and all the other things that would normally be charged to a foreign country to launch off of one of our pads, which would be like three times higher than that rate.

But that would be—it's called direct cost. I interpret that as additive cost. What it turns out to be is to be the same cost that we would charge any Government agency other than DOD to launch off that pad.

Mr. VOLKMER. Have you worked this out with the Department of Transportation in their commercialization program?

Mr. ALDRIDGE. We're in conference with them about the whole issue, and I talked to the people who are in charge of that office and mentioned that we are in agreement with that. And they're happy with that concept. I've been in—I haven't gotten into the specific details with them yet on that question, but that seems to be an agreement across the Department of Defense and I believe OMB.

Mr. VOLKMER. So if there would be any commercial, proposed commercial launches for private satellites prior to 1988, you're satisfied you already have sufficient——

Mr. ALDRIDGE. Yes, sir. I think the principle is applicable to across the board; yes, sir.

Mr. VOLKMER. And those people would know how much basically——

Mr. ALDRIDGE. Yes, sir. It would be——

Mr. VOLKMER [continuing.] They would have to pay on reimbursables?

Mr. ALDRIDGE. It would be different for each type of launch vehicle that you would fly.

Mr. VOLKMER. Now does the—as you stated last year, you fully supported—and I believe this year still you fully support—the need for spares for the orbiter fleet?

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. And does DOD intend to provide funds for procurement of orbiter spares?

Mr. ALDRIDGE. Sir, that was a question that was raised last year, and I went back to research that. The conditions by which we would agree to that would be if the administration made a decision to proceed with a fifth orbiter, that we in DOD would take funds from the phasing out of the existing ELV's and move them to NASA to fund for the spare parts to maintain the viability of the four orbiters, pending the completion of the fifth one.

The administration did not make a decision to proceed with the fifth orbiter, but in fact told to use those funds for spare parts. So

the conditions under which we would transfer did not occur, so we used those funds ourselves for funding some additional requirements that we had, such as fixing the IUS.

Mr. VOLKMER. But what if the Congress and the administration would make a decision to proceed next year with the fifth orbiter?

Mr. ALDRIDGE. Unfortunately, the funds that were available in last year's budget and not in the future budget, so we don't have the funds that we identified. Those funds identified were for the completion of the expendable launch vehicles that we were terminating. Those expendable launch vehicles were no longer capable of launching future DOD payloads because we have modified our payloads to go on the shuttle. So the plan would be to phase out of those expendables. Those funds would be transferred to NASA in that fiscal year. Unfortunately, those funds are no longer there, and they're not in the fiscal 1985 budget.

Mr. VOLKMER. Now I know it would be conjecture and speculation, but assuming that the question of being able to have full lift capacity as required for DOD launches by the shuttle are fully satisfied and being able to perform, and that the turnaround time, reliability, et cetera, meets present projections for the period of 1988 through 1992, and the shuttle is operating just as good as gold and doing everything everybody wants it to, will you still use ELV's for two flights, even though you had availability on the shuttle?

Mr. ALDRIDGE. Yes, sir. Otherwise, we would not have an ELV program.

We believe it requires DOD to step up to this commitment in order to make a viable commercial ELV activity.

Mr. VOLKMER. Are you saying, then, basically you're just buying insurance?

Mr. ALDRIDGE. I guess you could put a lot of words of description on that, but it's—in my view, it's buying assured access to space, and it's buying a—I won't use the word robust—it's buying a responsive space launch capability.

Mr. VOLKMER. It's the same capacity as what you're looking at? You're not looking at a different capacity, payload?

Mr. ALDRIDGE. No, sir.

Mr. VOLKMER. It's the same thing.

Mr. ALDRIDGE. It would be launching the same payloads that would be launched on the shuttle, that could be launched on the shuttle.

Mr. VOLKMER. And you don't consider that in any way a waste of taxpayers' dollars?

Mr. ALDRIDGE. No, sir, I do not. We're placing $9 billion a year into the national security space program, and this cost that we're talking about is not really taxpayer cost, if in fact the launch cost of an ELV is the same as the launch of the shuttle.

Mr. VOLKMER. Except that the shuttle is not utilized and that is wasted when it's available for you to use, and you're merely duplicating it?

Mr. ALDRIDGE. If the shuttle—if the rides that we remove from the shuttle can be resold, and I conclude that it maybe can in fact be resold, then there is no additional cost to the taxpayer because the launch costs are the same for——

Mr. VOLKMER. I agree on that——

Mr. ALDRIDGE. OK.

Mr. VOLKMER [continuing]. If it's sold.

Mr. ALDRIDGE. If it's sold.

And the view that I have speculated, then, is that if the DOD launch-on-demand requirements can be removed from the shuttle because commercial firms are concerned about the preemptive rights of DOD to bump them if they committed to the shuttle, we would begin removing those constraints on the shuttle and I think encourage commercial users to come onto the shuttle where they can launch on a better and more routine and planned schedule.

Mr. VOLKMER. Now——

Mr. MACKAY. Excuse me—go ahead.

Mr. VOLKMER. I just want to go with one further thought that's entered my mind.

That is we have a lot of old Titans left, don't we?

Mr. ALDRIDGE. We have 56. We will have 56 when they're fully decommissioned.

Mr. VOLKMER. Are you planning to use any of those in this operation?

Mr. ALDRIDGE. Not in this operation. We are studying how we might be able to use those Titans for the future. No decision has been made as to how.

Mr. VOLKMER. There's a possibility of using them for ELV's?

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. And if you had 56 to use instead of 10——

Mr. ALDRIDGE. No, sir, a different configuration. The Titan II's that we're pulling out of the silos are not anywhere close to the capability that exists for an Atlas or a Titan Centaur. It would not be utilized——

Mr. VOLKMER. You wouldn't be looking at those to make changes with them and——

Mr. ALDRIDGE. Not for the payloads——

Mr. VOLKMER. The lift capacity of a Titan Centaur then?

Mr. ALDRIDGE. No, sir, they would not be in that category at all. They would, in fact, however—and we're studying the issue—be capable of launching much smaller payloads.

Mr. VOLKMER. Milstar or the——

Mr. ALDRIDGE. No, sir, not Milstar. A couple of the candidates would be weather satellites or the GPS——

Mr. VOLKMER. Global positioning——

Mr. ALDRIDGE. The GPS system, yes, sir. That would be the class of vehicle that they could launch.

Mr. VOLKMER. And if you took the Global positioning out of the shuttle program?

Mr. ALDRIDGE. Let me explain that. The global positioning system takes about a third of the shuttle bay, and, therefore, we pay a third of the ride cost.

Mr. VOLKMER. You can put about three of them in there if you want to?

Mr. ALDRIDGE. You can put three of them in there, but the plan would be to fly only one of those, plus fill up the rest with commercial payloads of some sort. That is a very cheap way to get to space. In fact, it's very economical. We're going to have a multiplicity of these systems in orbit. The best way to get those in orbit is to use

the shuttle to fly them to orbit as we're filling out the constellation, and that's our plan of attack. We can, therefore, plan each orbit in a preplanned way, and if we can get another group of commercial firms or other Government users to go along with us on any given day, we can preplan that as we fill out the constellation. The concern is when we have a failure—back to launch-on-demand—of a particular satellite in a particular orbit that has to be replaced. We cannot afford to fly a complete shuttle load up to replace one satellite. That is uneconomical for us. There is a case where a Titan II vehicle might be appropriate to replace, launch-on-demand, a single satellite at a particular orbit on a particular day. And that's what we're looking at as a possibility. This, again, augments the shuttle. We no longer have to bump somebody to go replace a GPS. We can do it with an ELV launch-on-demand as it sits there any time we want to go, and not place any additional pressure on the shuttle program.

Mr. VOLKMER. Where are you planning to investigate the possible use of the Titans, the 56?

Mr. ALDRIDGE. The Air Force has prepared a study on that issue. They're coming to me this year. We will address it in our fiscal year 1986 budget preparation. It will have to compete with the funding priorities in our defense budget and the Air Force budget for fiscal 1986.

Mr. VOLKMER. You're looking there at what—the question of modifications and——

Mr. ALDRIDGE. Yes, sir. There are assets which are free to us. We'd have to go through some engine refiring program to make sure they were viable and some modifications to the shroud to put the vehicles on the top as we remove the reentry vehicle, and those kinds of things would have to be done.

Mr. VOLKMER. Now you twice used the statement, once on your ELV's and now on the use of the Titans for the GPS, and that is launch-on-demand.

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. I would just like to have your idea of what you mean by launch-on-demand. What's the timeframe—1 day, 1 week, 2 months, or 3 months?

Mr. ALDRIDGE. It would depend upon the satellite that you're talking about. We probably in a GPS launch-on-demand—we could afford several months because the constellation is fairly robust. There's quite a few of them, and it would degrade gracefully. So that timeframe for that would be much longer. Some of the more sensitive national payloads, we're talking about weeks and no longer. We would really need to replace them very, very rapidly.

Mr. VOLKMER. Now are you envisioning to use the—one of the three types of ELV's for this type of launch?

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. And are you envisioning, then, that the vehicle with payload would be integrated and placed at the cape in a storage position ready to go?

Mr. ALDRIDGE. That's the anticipation. The details of all this would be worked out depending upon the type of payload we decide, which has yet to be determined, and the arrangements where in the cape—the plan would be to use launch complex 40,

which has already launched Titan III's. We would either modify that for an Atlas or a minor modification for a Titan, and we would have to work out the details of how the scheduling of that payload, where we would store it in anticipation of launch, and those kinds of things. I don't have any details on that at this point.

Mr. VOLKMER. Would you have to provide not presently available storage facilities?

Mr. ALDRIDGE. It's not our intent to do that, sir. I believe the storage facilities currently exist.

Mr. VOLKMER. Does the gentleman from Florida have any additional questions?

Mr. MACKAY. Thank you, Mr. Chairman. What concerns me is that, although I don't challenge the legitimacy of your decision, it would seem to me that it has side effects that are almost greater than the main effect you're trying to reach. You are basically—you have made a decision to develop a competing delivery vehicle, to do it commercially, and you're saying that you think it can, for the same cost, be more robust, which I take to mean stronger, more dependable, with greater excess capability than what can be designed into the shuttle. And it would seem to me if you commercialize it, you are going to then be saying to all the other commercial users, "America now is going to compete with itself." We're not only going to compete with Ariane; we're going to compete with ourselves. You might have the option of bidding for NASA, which has the opposite of robust, a fragile, not flexible, not overdesigned system, but one that is operating at 100 percent of capacity each flight. It is not less expensive. It is not less flexible. And we've decided that we're going to operate this competing system. I almost could say, "Guess what the others are going to decide?"

Mr. ALDRIDGE. Let me——

Mr. MACKAY. What I'm saying is——

Mr. ALDRIDGE. I understand.

Mr. MACKAY. It looks to me as if you have made a decision that carries with it sort of the end of the role of the shuttle system for what a number of us had thought it would be designed for. I'm not criticizing you. Maybe this is the first time we have understood a realistic assessment of the shuttle system. Maybe we've designed a dinosaur. What will it be used for if you and the other commercial users decide that we're going to go to expendables? What will it be used for except an occasional recovery of something that we might want for the Smithsonian?

Mr. ALDRIDGE. The competition——

Mr. MACKAY. Let me just——

Mr. ALDRIDGE. OK.

Mr. MACKAY. If that's the conclusion that you've reached in a hard-headed fashion, and presumably with the support of OMB, why should we put anything—the real question is, Why should we put any more money into the shuttle?

Mr. ALDRIDGE. Because we're still going to fly 22 missions a year off the shuttle.

Mr. MACKAY. Until 1988.

Mr. ALDRIDGE. No, sir. We're going to fly 22 missions a year, as far as I know, at least until we decide what we're going to do to

replace the existing 4-orbiter fleet. The plan is 24 missions per year, is what our current plan calls for.

Mr. MACKAY. "We" is not DOD?

Mr. ALDRIDGE. "We" is talking about the country in this particular case. And it is clear that the country needs a robust—I'm going to use it again—and viable orbiter fleet to maintain the 22 missions a year, that 8 to 10 will be DOD, and the rest will be several commercial, foreign users, and it's clear that we have to have a viable fleet to do that.

Mr. MACKAY. But the civil, commercial, and foreign users have an option, and they're going to look at—and we would expect them to look——

Mr. ALDRIDGE. Right.

Mr. MACKAY [continuing]. At their best option. What you're saying is we believe that the competitive one we're about to design will be a better option.

Mr. ALDRIDGE. Right now the option is——

Mr. MACKAY. So we can use the other two-thirds——

Mr. ALDRIDGE. I understand. The option right now is shuttle or Ariane.

Mr. MACKAY. Well, I understand that.

Mr. ALDRIDGE. Now we're saying there's another option.

Mr. MACKAY. One of the reasons that the shuttle is in the competition is DOD is hanging tight with it. Now if DOD says, "We're going to compete with Ariane," I'm saying, who uses the shuttle for what?

Mr. ALDRIDGE. The shuttle has a uniqueness of man. It has a uniqueness and a very economic viability because smaller commercial users that don't build payloads of 32,000 pounds or 65,000 pounds, depending on where you launch from, they are not talking about using the shuttle for those. We're talking about the big payloads going off the Titan or the Atlas, or whatever. The issue is the smaller commercial firms who don't build those big payloads can, in fact, fly on the orbiter much cheaper than they can fly off an ELV.

Mr. MACKAY. But suppose McDonnell Douglas or Martin Marietta or some new group comes forward and they get your contract to develop an ELV competing with Ariane. Are you saying to me they won't quickly develop the capability to haul small loads and sort of toss them out as they go along?

Mr. ALDRIDGE. But I think they would have a hard time competing at the launch rates we're talking about with the shuttle for that purpose. My view of this Titan or Atlas ELV is a competitor with Ariane and not a competitor with the shuttle. The payloads that Ariane launches are very large, geosynchronous, of the same class that our ELV could launch, and there's the competitor—the people who are going to look at, one, an Ariane, which does not have a very successful reliability rate at this point versus a U.S. expendable, either of which has a very highly reliable launch capacity and a production base for that. I believe we'll be in the view of competing with Ariane and not necessarily competing with the shuttle. The shuttle has that uniqueness of manned and uniqueness of being able to launch a lot of smaller payloads very inexpen-

sively for commercial or civil users, and that uniqueness will always exist.

Mr. MACKAY. You made a statement that I may have misinterpreted. I understood you to say that you had an agreement with NASA for cost through 1988.

Mr. ALDRIDGE. Yes, sir.

Mr. MACKAY. And that you—I understood you to say, or I felt you implied, that you would review your position in 1988 when that agreement came up again.

Mr. ALDRIDGE. The agreement is only through 1988 and is required to be reviewed between NASA and ourselves at that point.

Mr. MACKAY. And, so, let me then carry forward the other assumption. If you know that you can be competitive with the costs that you have now locked in, and you find in 1988 that NASA can no longer hold to this cost, so that your cost is now less, you would have the option in 1988 not to put further payloads on the shuttle?

Mr. ALDRIDGE. That option would exist, yes, sir. Whether or not we would exercise it would depend upon what is the cost to us to now modify additional payloads to go on the ELV, which is in up front dollars, and——

Mr. MACKAY. You're putting us—in fairness, Mr. Aldridge—you're putting us on notice now that somewhere, either in DOD or in OMB, a decision has been made either to hold costs constant and to try to get greater flexibility and greater dependability or else to get the same flexibility and dependability and go for less cost, and that in 1988 you're going to make that decision on those parameters?

Mr. ALDRIDGE. The decision of what those costs will be is NASA's proposal of what they will be. As we negotiated with them 2 years ago, Jim Beggs provided a cost. He said that we believe, based upon the principles that we agreed to, that the $29.8 million in 1975 dollars was a fair price. We agreed. In 1988—and that will probably exist before 1988—but he will submit another proposal to us, hopefully based upon the same principles, and we will have to consider whether those costs are reasonable or not, and I believe the Congress last year said that the price is that which is negotiated between buyer and seller, and whatever is fair, and we agree with that. Whatever is fair, we're willing to pay.

Mr. MACKAY. You're the largest user, and you're developing a competing system.

Mr. ALDRIDGE. No, sir. We are—we fly—total DOD is one-third of the total flights, and the ELV we're talking about is 2 out of 24. So there's 22 that would remain based upon their mission model.

Mr. MACKAY. I understand that, but when you negotiate with the commercial contractor to fly your loads with the ELV, you're not going to negotiate that you will be his exclusive user, are you?

Mr. ALDRIDGE. No, sir.

Mr. MACKAY. You're, in effect, going to pay his startup costs, so that he can go out and promote the people who are now choosing between Ariane and NASA.

Mr. ALDRIDGE. That is correct.

Mr. MACKAY. OK.

Mr. VOLKMER. Would the gentleman yield?

Mr. MACKAY. You don't see that as being the end of the shuttle program?

Mr. ALDRIDGE. No, sir.

Mr. VOLKMER. Would the gentleman yield? Let's just take that one step further. I think we all recognize—and even NASA and I think private industry recognize—that payloads for the shuttle are going to get heavier weight per payload. They're not going to stay—even in communications, they're not going to stay in the area where they currently are. As a result, we see a program known as the TAS program, private individuals, developing that. And what I see here is a direct competition with that. Correct or incorrect? What are you looking at as payload capacity for your ELV? You are not looking at 2,000 or 2,500.

Mr. ALDRIDGE. We want to place 10,000 pounds in geosynchronous orbit.

Mr. VOLKMER. 10,000 pounds, geosynchronous orbit, direct competition.

Mr. ALDRIDGE. But there are only very few people who have 10,000 pounds going to geosynchronous orbit.

Mr. VOLKMER. At the present time.

Mr. ALDRIDGE. At the present time.

Mr. VOLKMER. In 1988 and 1992 there may be others.

Mr. ALDRIDGE. That is conceivable, yes, sir.

Mr. MACKAY. Mr. Chairman, with apologies——

Mr. VOLKMER. Yes.

Mr. MACKAY. As I understand the commercial ELV plan, you would ask the contractor to fund the up front R&D; you would commit to buy at least 2 vehicles a year for 5 years; you would buy at a rate that would allow him to amortize his up front R&D across the first 10 vehicles. So you're taking the risk, and you would guarantee termination liability if it's canceled.

Mr. ALDRIDGE. Yes, sir.

Mr. MACKAY. Is that not a subsidy for the development of a program that will duplicate and compete with the shuttle?

Mr. ALDRIDGE. No, sir, I don't believe that's a subsidy.

Mr. MACKAY. Well, the risk is yours, is it not?

Mr. ALDRIDGE. All of these details have yet to be worked out as to exactly what the precise financing arrangement and what type of contingent liability would have to be placed upon the—we would make a commitment to the Air Force and the Department of Defense. Those are still to be worked out. However, that would be the intent. In concept, yes, we would--if, for some reason other than the fault of the contractor, we elected that this plan would no longer be viable, we would pay for his incurred cost to develop this capability.

Mr. VOLKMER. Does the gentleman from California have any questions?

Mr. MINETA. Mr. Chairman, thank you very much. And I apologize, Secretary Aldridge, for not being here when you gave your testimony. It's good to have you here before us. I was at the other committee that you sometimes appear before, the Intelligence Committee. I'm wondering—it's come to my attention that the estimated time for processing this Centaur-G or G' through the cape OPF and integrating with the orbiter is much longer than had been an-

ticipated, perhaps twice as long as for a PAM-D stage. Now the number of shuttle flights in a year could be limited as a result. I'm wondering, would the use of an Air Force ELV flying a Centaur-G stage relieve the potential NASA schedule problem of processing the shuttle with Centaur?

Mr. ALDRIDGE. Yes, sir; the factors that we've looked at with the processing time and the delays for Centaur as opposed to some other upper stage, it appears to us that the actual availability would be that we could fly another shuttle mission if we could remove that Centaur mission from the processing period. So it would actually free up NASA having the availability of another mission ride, just because we've removed the Centaur from the mission model.

Mr. MINETA. And is there any thought of doing that?

Mr. ALDRIDGE. Well, as far as our ELV plan is, yes, sir, that would be the thought, that we would fly two per year, two Centaur ELV's per year, so that you would, in fact, free up at least two more—provide at least two more Centaur or shuttle rides per year that would not use Centaur.

Mr. MINETA. NASA is studying a new, unmanned launch vehicle known as the SRB-X, and this may be for heavy lift purposes or it could also perform shuttle-equivalent missions. Can the Air Force substitute the SRB-X for the commercial ELV program that you have described to us?

Mr. ALDRIDGE. There's a possibility, but it's very expensive and it delays in time. Our requirement is for 1988 to meet the requirement, and we don't anticipate you could have an SRB-X in the 1988 timeframe. The only vehicles available in that timeframe would be modifications of the existing ELV's. The up front dollars would be in the order of $700 to $800 million of up front R&D cost to develop such a capability, and it would also require us to modify the pad at ETR to fly these missions at the same time we're trying to fly the shuttle off of the same pad. And while it is theoretically possible to have an SRB-X vehicle for this complementary system, the timeframe and the dollars really have great disadvantages to us. It looks like we would not be in the view of providing that capability with that vehicle.

Mr. MINETA. The WTR, the Vandenberg facility, did you say that you're hoping to be operational out there in—did I see in your statement in October 1985?

Mr. ALDRIDGE. Yes, sir.

Mr. MINETA. So you're—given the slippage we've had up to this point, this is what you're holding and counting to right now?

Mr. ALDRIDGE. Yes, sir. It's tough, and the schedule is very tight, but we're anticipating—I talked to Forest McCartney last night again on this issue, and he assures me we're going to make every attempt to make it in October 1985.

Mr. MINETA. As I understand it, there is some problem as it relates to the icing on the external tanks and the stiffness of the launching pad as it relates to Vandenberg. Has that been dealt with?

Mr. ALDRIDGE. Yes, sir. The icing thing was a matter of just getting under contract with some language that we had to accommodate on the Hill about competition for that particular facility. I be-

lieve we're now on track on that and still shooting for the October 1985. The stiffness I believe is a question of the—I think they call it the twang of the launch, and I believe those design problems have now been overcome. If there is any other information, I'll provide it for the record, if there is any new information on that.

[The information follows:]

The response on the External Tank Ice Suppression System project is correct. The modification to the launch pad is in progress with anticipated completion date of April 1984. The rest of the construction for this project is located off the launch pad itself and will be completed by November 1984.

The response on the launch mount stiffness is also correct. A joint NSAS/AF team studied the problem and modifications were made to the launch mount. Two "twang" tests, where the Solid Rocket Boosters are physically displaced and then released to simulate the dynamics of a launch, are scheduled. The first test will be with inert Solid Rocket Boosters and is schedule for the December/January time frame and will utilize steel cases. The second test is scheduled for May and will utilize Filament Wound Cases. These two tests will be used to verify the calculations performed by the NASA/AF team.

Mr. MINETA. There are no other surprises as it relates to Vandenberg that are contemplated in October 1985?

Mr. ALDRIDGE. I hope there are no more surprises between now and 1985. We are virtually complete in the construction of the facility. The surprises will occur when we begin to hook the pieces together and start the test period. Obviously, we have some—the scheduling takes into account that testing, and if we're surprised, it could, in fact, impact upon that launch. However, I'm not anticipating that if it impacts us—we're not talking about significant impacts. It may be a few weeks of delay or something like that, but I'm not anticipating there will be any major delays any further. Our construction has gone very well, once the concept began to settle down and we began working to a common baseline, and yet we've still got problems in terms of the tightness of the schedule, but I think we'll make this date. The biggest problem, I believe, is not so much that first launch date; it's what is the rate of launch that you can sustain after that particular date. Right now we're planning for the first year to be able to launch three vehicles from Vandenberg, and then four per year thereafter. And we don't see any problems in being able to do that.

Mr. MINETA. Thank you very much, Secretary Aldridge. Thank you very much, Dr. Cook. It's always good seeing you. Thank you, Mr. Chairman.

Mr. VOLKMER. I know this has lasted quite long, but it's a topic, of course, none of us were thinking we'd ever face, anyway. It's just recently come up, so I'm sure you understand the time we put on it.

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER. Correct me if I'm wrong in the conclusion that I draw that after 1988 we'll probably never see another shuttle-Centaur defense mission.

Mr. ALDRIDGE. No, sir, that's not correct.

Mr. VOLKMER. That's not correct?

Mr. ALDRIDGE. No, sir, that's not our intent.

Mr. VOLKMER. You wouldn't be using ELV's for those missions?

Mr. ALDRIDGE. No, sir, that's not the intent. Again, I can't speak for somebody who may be here in 1988, but——

Mr. VOLKMER. I mean, they'll do the same thing.

Mr. ALDRIDGE. But our intent is to only launch two per year. And it costs the Air Force and the Department of Defense funds to modify those payloads to be able to go either way, and there has to be some economic rationale put into the design of those systems. And right now our intent is not to do that, to pick only two that we'll launch on these ELV's and pay the price for the modifications to do that.

Mr. VOLKMER. But I think you can understand the concern of several of us that—in other words, like I said before, a year ago and 2 and 3 years ago this wasn't even contemplated, and now we see two a year. The question is, What happens in 2 years or 1 year or 3 years from now—how many? The other thing that concerns us is you're looking at use of the old Titans for smaller payloads. You'd have 56 of them. And if you're looking at them for just one or two GPS's, they could also—even though you assure us that it wouldn't be done—some of us feel that there's a possibility that all the GPS's could go up on those Titans——

Mr. ALDRIDGE. Yes, sir.

Mr. VOLKMER [continuing]. And those implications. It concerns some of us.

Mr. ALDRIDGE. But, sir, let me turn the issue around to the point of view of how I have to look at this particular problem. My job is to put spacecraft in orbit to support vital national security needs. My mission is not worrying about launching the orbiter or launching a Titan II or launching an ELV. My mission is to put payload into orbit, and I have to find the best way to do that. And I don't believe relying on a single launch system supports that mission that I am tasked with doing. And what I'm doing is trying to find the system that will give me reliable, on-time capability to replace spacecraft when we need to. And whatever that purpose, whatever that mechanism is and whatever that system is to launch those spacecraft is what I'm looking for. Right now we do not have a reliable, responsive launch capability for the future, and I think we need to augment that with an ELV capability to give us that reliable access and assured access to space.

Mr. VOLKMER. I have to disagree with the statement that we don't have a reliable launch capability for the future. I think that we're building to that, and I think it's there, and——

Mr. ALDRIDGE. Well, I understand, and——

Mr. VOLKMER. That's probably the area where we have some disagreement.

Mr. ALDRIDGE. Well, if things worked perfectly—and I made this point before in my statement—if things worked perfectly, which they do not, then the shuttle fleet, as you pointed out before—if it's working and the turnaround times are there, everything is working perfectly, could we do with the shuttle? Absolutely, if things worked perfectly. The question is, Do we want to depend upon things working perfectly for the future? And I, as a user for national security purposes, believe that we need to augment that system with insurance to make sure we can get to space, and I believe we need that additional insurance at this point.

Mr. VOLKMER. And every ELV—I know we've had a good history in the Atlas and everything, but they can fail, also.

Mr. ALDRIDGE. Yes, sir. We have seen the results of the old wheat field Atlas failing in some of our launches. And, unfortunately, that's——

Mr. VOLKMER. I mean, it can happen.

Mr. ALDRIDGE. It can happen, both sides.

Mr. VOLKMER. Upper stages, things can go wrong.

Mr. ALDRIDGE. Unfortunately.

Mr. VOLKMER. So you're not telling us, then, you're getting that 100 percent reliability?

Mr. ALDRIDGE. No, sir, but I sure wish I had another way to launch satellites other than IUS at this point. [Laughter.]

Mr. VOLKMER. I do, too. Does anyone else have any further questions?

[No response.]

Mr. VOLKMER. Thank you very much, Secretary Aldridge. We appreciate it. Our next witness will be Ian—is it Pryke?

Mr. PRYKE. Pryke.

Mr. VOLKMER. Washington office of the European Space Agency. Your statement will be made a part of the record in full, and you may either summarize or review it in full, however you so desire.

STATEMENT OF IAN PRYKE, HEAD OF THE WASHINGTON OFFICE, EUROPEAN SPACE AGENCY

Mr. PRYKE. Thank you, Mr. Chairman.

Mr. VOLKMER. I just want to say for the following witnesses that we have yet today, we will continue to go on, even—if they have no disagreement—right through the lunch hour, if necessary.

Mr. PRYKE. Thank you, Mr. Chairman. The director general of the European Space Agency has asked me to express his appreciation at being requested, once more, to testify before this Subcommittee, and to convey to you his regrets at not being able to be here in person. He will be happy to provide written answers to any questions you may wish to submit to him, and I'm available to address such questions as you may have at this time. As you requested in your letter of invitation, the majority of this testimony deals with the status of existing cooperative endeavors between ESA and the United States, areas of potential future cooperation, and possible collaboration on the space station program as a separate item. Also, for informational purposes, I have taken the liberty of including a limited amount of material on the ESA programs of a purely European nature. I will submit the whole of the testimony for the record and will address at this time only those items of particular interest to the subcommittee.

The major event in 1983 for ESA was, without a doubt, the STS–9/spacelab 1 mission. Although spacelab pallets had flown aboard the shuttle on previous occasions, this as the first flight for the complete spacelab system and represented the culmination of over a decade of cooperation between ESA and NASA on the program. Spacelab was designed and built in Europe with European funds, under the direction of ESA. In fulfillment of the intergovernmental agreement between the Uintied States and the European states involved in the program, and the MOU between ESA and NASA, one engineering model, one set of flight hardware, and two sets of

ground support equipment have been delivered free of charge to NASA. An ESA/European contractor team has been in residence at KSC supporting the integration of the spacelab 1 mission and will continue to provide engineering support through the spacelab 2 mission.

The mission itself on spacelab 1 was rated by both ESA and NASA as a tremendous success, with all spacelab systems performing in accordance with specifications. The only major system anomalies reported were the breakdown of a high data rate recorder, which was subsequently fixed by the crew, and the intermittent operation of a remote acquisition unit on the pallet. All experiments within the payload were operated, and the only major failures experienced in the European portion being the failure of our microwave remote sensing system to operate in its active mode, the failure of the isothermal heating facility after 12 of a planned 22 samples had been processed, and the incomplete processing of 6—sorry, of 2 out of 6 samples in the mirror heating facility. Data collected by some experiments was degraded due to the slip in the launch date to late November. We have, however, been working with NASA to identify reflight opportunities for these experiments, and to date all experiments have been placed, with the exception of the metric camera.

Based on the above, I think it's true to say that in both Europe and the United States the spacelab program is considered to be the largest and most successful example of international space cooperation in history.

Work continues in Europe on the spacelab follow-on production program in which additional spacelab flight hardware procured by NASA, under the terms of the NASA-ESA MOU, is being fabricated and delivered to the United States. As currently planned, deliveries should be completed in 1985, and not 1986 as in my written testimony.

Within the so-called spacelab follow-on development program, ESA is undertaking the development of a European retrievable carrier, EURECA. The EURECA platform will provide a capability to support experiments in space for periods well in excess of the maximum on-orbit shuttle stay time. For the first EURECA mission, the schedule calls for it to be deployed from the shuttle on flight 81-A in October 1987 and retrieved and returned to Earth on flight 81-L in May 1988. The majority of the first payload will consist of microgravity experiments, including five or six core facilities that are being developed by the European Space Agency. We are discussing with NASA the possibility of some U.S. experimenters flying a limited number of samples in these facilities on the first mission. Utilization of EURECA by NASA for future missions, possibly within the context of the international microgravity program, is also being reviewed. The provision of other European microgravity facilities, developed for spacelab missions, for use on the international microgravity program is also a possibility, and we are meeting regularly with NASA to assess the potential for cooperation within this area.

As far as the Ariane program is concerned, I will only say that in 1983 we had two successful launches. One involved our ECS operational telecommunications satellite, and the other launch was of an Intelsat 5. The next launch in the series, L8, is currently

scheduled for the 4th of March and will carry another Intelsat 5. With the exception of the launch of the third Intelsat—of a third Intelsat, I'm sorry—in 1985, this will be the last launch directly under ESA control. Future launches will become the responsibility of Arianespace, the commercial company, incorporated under French law, to manufacture, market, and launch future vehicles.

In the area of space science, a number of programs merit mention. On the 16th of May last year, ESA's EXOSAT spacecraft was launched from the Western Test Range on a Delta 3914 vehicle. The launch was a complete success and represented a record of sorts for the Delta team, in that they met their shortest ever launch window, 1 minute in duration. In fact, they launched 40 milliseconds late, but we weren't ready to complain. EXOSAT is still in operation and continues to return excellent data. Cooperation with NASA has continued throughout the year in both the ISEE program, in which ESA has one operational spacecraft, and the international ultraviolet explorer program, in which ESA has contributed the solar array and a ground observatory. As regards the Hubble space telescope, ESA's hardware contributions, the solar arrays plus one of the focal plane instruments, the so-called faint object camera, are being delivered as planned. Remaining technical problems, which are unavoidable in a project of such high complexity and sophistication, are being discussed between ESA and NASA in an excellent spirit of cooperation. ESA is contributing to the space telescope project at a level of about 15 percent, including a total of 15 scientists that we have assigned to the Space Telescope Institute now open in Baltimore.

The International Solar Polar Mission spacecraft development has been completed and the spacecraft is presently in storage in Europe. Current planning calls for its delivery to the United States in early 1985, in preparation for a May 1986 shuttle launch. The spacecraft will carry experiments developed by both European and American investigators.

Work also continues on ESA's Giotto spacecraft, which is due to be launched to Halley's Comet in July 1985. All experiments have European principal investigators, but a number of U.S. coinvestigators are involved in the mission. NASA continues to provide support in the mission analysis area, and we will make use of the deep space network of NASA as a backup data acquisition facility during the encounter phase with the comet. It is worth noting here that ESA, NASA, the Japanese and the Russians have joined together to form the interagency consultative group for the exploration of Halley's comet. NASA–JPL and the U.S.S.R. mission will be assisting ESA in targeting Giotto to approach the nucleus of the comet at a distance of about 500 kilometers, which will be the closest approach of all planned missions.

During the past year ESA's Science Program Committee approved the Agency's latest science new start, the so-called Infrared Solar Observatory, scheduled for launch in the early nineties. Coordination between ISO and NASA's SIRTF program is being discussed by the two Agencies.

In the area of future science projects, planning review meetings are held on a regular basis, and joint studies on potential future cooperative ventures are being carried out. The intention is to,

where possible, coordinate planning between the Agencies and avoid a wasteful duplication of effort. The potential for a particularly promising cooperation is foreseen within the framework of the international solar terrestrial physics program. American, European, and Japanese participants are each planning the launch of one or more satellites for a program of coordinated exploration of our planet's near environment and how it is influenced by solar and interplanetary phenomena. Cooperative projects in planetary science and astronomy are also being studied. We also have continuing discussions between ESA and NASA, and between groups of United States and European scientists on the principles and modalities of the reciprocity of flight opportunities, to allow the different scientific communities flight opportunities on each other's projects. This is considered a delicate subject by all parties, but progress is being made in a frank and cooperative spirit.

I shall now go on to Earth observations, Mr. Chairman. The cooperation on Earthnet, which involves the European acquisition of data from U.S. remote sensing satellites, particularly those of the Landsat program, continues to operate successfully. In early 1983 Earthnet had acquired some 1,300 thermatic mapper scenes from Landsat 4. Acquisition of MSS data continues satisfactorily to date. With the transfer of responsibility of LANDSAT from NASA to NOAA, a new ESA/NOAA MOU has been negotiated, is approved by both parties, and ready for signature. ESA's oceanographic remote sensing satellite program, ERS–1, is currently in a phase B extension, which is scheduled to be completed by March of this year. A phase C/D/E proposal—E being the operational phase—was submitted to participating States in December 1983 with approval being sought in mid-1984. The planned launch date is mid-1988. Fruitful discussions are taking place with NASA on various aspects of this mission. Plans are being made for a second flight unit of ERS–1 to be launched 2 to 3 years after the first one, to provide data continuity over an extended period. We're also working on the definition of an advanced land mission for the early nineties.

The next so-called multilateral remote sensing meeting, which involves those various countries actually producing remote sensing spacecraft, is scheduled to be hosted by the United States in Washington in June 1984. These meetings have in the past provided a useful forum for exchange of information and technical coordination between operators of remote sensing satellite systems.

As the final, and in all probability the most important, topic of my testimony, I would like to address the matter of ESA's possible cooperation in the U.S. space station program. ESA has been entrusted by its member states with the task of studying possible options in the area of space transportation beyond the systems currently under development, these being Ariane IV, spacelab, and EURECA, and of preparing an overall European long-term policy in this area.

As regards orbital systems, one option involves participation in the planned U.S. space station. The others are of a more independent European approach. As regards the space station, we have examined how our current expertise could be used. Although no final answer exists, spacelab-derived elements look very promising as

candidate components for a space station. We also feel that the EURECA platform would represent a good candidate for a type of platform to be serviced from a space station.

In the establishment of any collaboration, we would be looking for certain conditions to be fulfilled. Of particular importance would be that our share of the work would be such as to provide a major stimulus to European technology. Furthermore, whatever the final choices of hardware, Europe would want to have a clearly defined role in the operational phase of the space station. Furthermore, ESA would want its participation to be visible, that is to say that it will aim at identifying one or more elements with clear interfaces over which it will exercise full responsibility. Finally, on the basis of its collaboration in the program, ESA would want to have access to the entire space station capability and not only to the element or elements it may possibly develop. After the success of spacelab, Europe is considering very favorably further involvement in manned space systems. Having demonstrated the quality of European-made manrated space hardware and its ability to manage large cooperative programs, ESA considers that solid grounds exist for entering on a partnership basis in the space station development. ESA is of the opinion that advantageous conditions for both partners could be found in the space station development and utilization, and, therefore, a substantial participation of Europe could be achieved which will enhance the overall value of the space station program.

In conclusion, Mr. Chairman, I would like to state that, as is evident from the content of this testimony, the Agency and its member states continue to be fully committed to the concept of international cooperation in space activities, in particular the cooperation with the United States. Such cooperation has in the past yielded benefits to all parties involved, and is certain to do so in the future. For the Agency's part, we will continue to work with NASA to foster such cooperative endeavors, to our mutual benefit, wherever the opportunity arises.

That concludes my prepared testimony, Mr. Chairman.

[The prepared statement of Mr. Pryke follows:]

european space agency
agence spatiale européenne
europäische weltraumorganisation

S T A T E M E N T

BY

MR. IAN PRYKE

HEAD OF THE WASHINGTON OFFICE

OF THE EUROPEAN SPACE AGENCY

BEFORE THE HOUSE COMMITTEE ON

SCIENCE AND TECHNOLOGY

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

FEBRUARY 23, 1984

955 L'Enfant Plaza, S.W., Suite 1404, Washington, D.C. 20024 Tel. (202) 488-4158 — Telex 64412

THE DIRECTOR GENERAL HAS ASKED ME TO EXPRESS HIS APPRECIATION AT BEING REQUESTED, ONCE MORE, TO TESTIFY BEFORE THIS SUBCOMMITTEE, AND TO CONVEY TO YOU HIS REGRETS AT NOT BEING ABLE TO BE HERE IN PERSON. HE WILL BE HAPPY TO PROVIDE WRITTEN ANSWERS TO ANY QUESTIONS YOU MAY WISH TO SUBMIT TO HIM, AND I OF COURSE AM AVAILABLE TO ANSWER, TO THE BEST OF MY ABILITY, ANY QUESTIONS THAT YOU HAVE AT THIS TIME.

IN LINE WITH YOUR LETTER OF INVITATION THE MAJORITY OF MY TESTIMONY DEALS WITH:

- THE STATUS OF EXISTING CO-OPERATIVE ENDEAVOURS
- AREAS FOR POTENTIAL FUTURE CO-OPERATION
- COLLABORATION ON THE SPACE STATION PROGRAMME.

FOR INFORMATION PURPOSES I HAVE ALSO INCLUDED A LIMITED AMOUNT OF MATERIAL ON THE ESA PROGRAMMES OF A PURELY EUROPEAN NATURE.

WITH YOUR PERMISSION I WILL SUBMIT THE WHOLE OF THE TESTIMONY FOR THE RECORD AND WILL ADDRESS, AT THIS TIME, ONLY THOSE ITEMS OF PARTICULAR INTEREST TO THE SUBCOMMITTEE.

SPACELAB

THE MAJOR EVENT IN 1983 FOR ESA WAS, WITHOUT A DOUBT, THE STS-9/SPACELAB 1 MISSION. ALTHOUGH SPACELAB PALLETS HAD FLOWN ABOARD THE SHUTTLE ON TWO PREVIOUS OCCASIONS, THIS WAS THE FIRST FLIGHT FOR THE COMPLETE SPACELAB SYSTEM, AND REPRESENTED THE CULMINATION OF OVER A DECADE OF CO-OPERATION BETWEEN ESA AND NASA ON THE PROGRAMME.

SPACELAB WAS DESIGNED AND BUILT IN EUROPE WITH EUROPEAN FUNDS, UNDER THE DIRECTION OF ESA. IN FULFILLMENT OF THE INTERGOVERNMENTAL AGREEMENT BETWEEN THE USA AND THE EUROPEAN STATES INVOLVED IN THE PROGRAMME, AND THE MOU BETWEEN ESA AND NASA:

- ONE ENGINEERING MODEL
- ONE SET OF FLIGHT HARDWARE
- TWO SETS OF GROUND SUPPORT EQUIPMENT

HAVE BEEN DELIVERED, FREE OF CHARGE TO NASA.

AN ESA/EUROPEAN CONTRACTOR TEAM HAS BEEN IN RESIDENCE AT KSC SUPPORTING INTEGRATION OF THE SPACELAB 1 MISSION AND WILL CONTINUE TO PROVIDE ENGINEERING SUPPORT THROUGH THE SPACELAB 2 MISSION.

STS-9/SL-1 WAS LAUNCHED FROM KSC ON NOVEMBER 28TH 1983 AND LANDED AT THE DRYDEN FLIGHT RESEARCH CENTER, CALIFORNIA, ON DECEMBER 8TH. THE FLIGHT:

- WAS THE LONGEST SHUTTLE FLIGHT TO DATE
- CARRIED THE LARGEST CREW TO DATE (6) INCLUDING THE FIRST NON-US CREW MEMBER, DR. ULF MERBOLD AN ESA STAFF MEMBER.

THE MISSION WAS RATED BY BOTH ESA AND NASA AS A TREMENDOUS SUCCESS. ALL SPACELAB SYSTEMS PERFORMED IN ACCORDANCE WITH SPECIFICATIONS AND REQUIREMENTS THROUGHOUT THE FLIGHT. THE ONLY MAJOR SYSTEM ANOMALIES REPORTED WERE THE TEMPORARY BREAK-DOWN OF A HIGH DATA RATE RECORDER, AND THE INTERMITTENT OPERATION OF A REMOTE ACQUISITION UNIT ON THE PALLET.

ALL EXPERIMENTS WITHIN THE PAYLOAD WERE OPERATED, THE ONLY MAJOR FAILURES EXPERIENCED IN THE EUROPEAN PORTION BEING:

- THE FAILURE OF THE MICROWAVE REMOTE SENSING EXPERIMENT TO OPERATE IN ITS ACTIVE MODE
- THE FAILURE OF THE ISOTHERMAL HEATING FACILITY AFTER 12 OF A PLANNED 22 SAMPLES HAD BEEN PROCESSED.
- THE INCOMPLETE PROCESSING OF 2 OUT OF 6 SAMPLES IN THE MIRROR HEATING FACILITY.

THE DATA COLLECTED BY SOME EXPERIMENTS WAS DEGRADED AS A RESULT OF THE SLIP IN THE LAUNCH DATE TO LATE NOVEMBER. HOWEVER, NASA AND ESA HAVE BEEN WORKING TOGETHER TO IDENTIFY REFLIGHT OPPORTUNITIES FOR THESE EXPERIMENTS, AND TO DATE ALL HAVE BEEN PLACED, WITH THE EXCEPTION OF THE METRIC CAMERA.

ALTHOUGH DIFFICULT TO DEFINE PRECISELY THE MISSION IS DEEMED TO HAVE BEEN ABOUT 95% SUCCESSFUL.

I THINK IT IS TRUE TO SAY THAT IN BOTH EUROPE AND THE USA THE SPACELAB PROGRAMME IS CONSIDERED TO THE LARGEST AND MOST SUCCESSFUL EXAMPLE OF INTERNATIONAL "SPACE" CO-OPERATION IN HISTORY.

WORK CONTINUES IN EUROPE ON THE SPACELAB FOLLOW-ON PRODUCTION PROGRAMME IN WHICH ADDITIONAL SPACELAB FLIGHT HARDWARE PROCURED BY NASA, UNDER THE TERMS OF THE NASA-ESA MOU, IS BEING FABRICATED AND DELIVERED TO THE USA. AS CURRENTLY PLANNED, DELIVERIES SHOULD BE COMPLETED IN 1986.

WITHIN THE SO CALLED SPACELAB FOLLOW-ON DEVELOPMENT PROGRAMME ESA IS UNDERTAKING THE DEVELOPMENT OF A EUROPEAN RETRIEVABLE CARRIER (EURECA). THE EURECA PLATFORM WILL PROVIDE A CAPABILITY TO SUPPORT EXPERIMENTS IN SPACE FOR PERIODS WELL IN

EXCESS OF THE MAXIMUM ON-ORBIT SHUTTLE STAY TIME. IN THE CASE OF THE FIRST EURECA MISSION, THE SCHEDULE CALLS FOR IT TO BE DEPLOYED FROM THE SHUTTLE ON FLIGHT 81-A IN OCTOBER 1987, AND RETRIEVED AND RETURNED TO EARTH ON FLIGHT 81-L IN MAY 1988. THE PLATFORM CAN CARRY A PAYLOAD OF ABOUT 1100 KGS, AND SUPPLY IT WITH APPROXIMATELY 1.7 KW OF POWER.

THE MAJORITY OF THE FIRST PAYLOAD WILL CONSIST OF MICROGRAVITY EXPERIMENTS, INCLUDING 5 OR 6 CORE FACILITIES THAT ARE BEING DEVELOPED BY ESA. ESA IS DISCUSSING WITH NASA THE POSSIBILITY OF SOME US EXPERIMENTERS FLYING A LIMITED NUMBER OF SAMPLES ON THE FIRST MISSION. UTILISATION OF EURECA BY NASA, FOR FUTURE MISSIONS, POSSIBLY WITHIN THE CONTEXT OF THE INTERNATIONAL MICROGRAVITY PROGRAMME, IS ALSO BEING REVIEWED.

THE PROVISION OF EUROPEAN MICROGRAVITY FACILITIES, DEVELOPED FOR SPACELAB MISSIONS, FOR USE ON THE INTERNATIONAL MICROGRAVITY LABORATORY IS ALSO A POSSIBILITY, AND ESA IS MEETING REGULARLY WITH NASA TO ASSESS THE POTENTIAL FOR CO-OPERATION WITHIN THE PROGRAMME.

ARIANE PROGRAMME

1983 SAW TWO LAUNCHES OF ESA'S ARIANE EXPENDABLE LAUNCH VEHICLE, BOTH OF WHICH WERE COMPLETELY SUCCESSFUL.

ON JUNE 16TH ARIANE L6 SUCCESSFULLY ORBITED ECS 1, ESA'S FIRST OPERATIONAL TELECOMMUNICATIONS SATELLITE, AND AMSAT P3B A RADIO AMATEUR SATELLITE. THIS LAUNCH DEMONSTRATED THAT THE PROBLEMS THAT RESULTED IN THE FAILURE OF THE L5 LAUNCH HAD BEEN CORRECTLY IDENTIFIED AND THE NECESSARY MODIFICATIONS MADE TO THE VEHICLE.

THE LAUNCH OF ARIANE L7 TOOK PLACE ON OCTOBER 18, FOLLOWING AN APPROXIMATELY ONE MONTH POSTPONEMENT MADE AT THE REQUEST OF THE CUSTOMER. THIS WAS THE FIRST LAUNCH OF AN INTELSAT V BY ARIANE.

THE NEXT LAUNCH (L8) CURRENTLY SCHEDULED FOR EARLY MARCH WILL INVOLVE ANOTHER INTELSAT V. WITH THE EXCEPTION OF THE LAUNCH OF A THIRD INTELSAT IN 1985, THIS WILL BE THE LAST LAUNCH DIRECTLY UNDER ESA CONTROL. FUTURE LAUNCHES WILL BE THE RESSPONSIBILITY OF ARIANESPACE, THE COMMERCIAL COMPANY, INCORPORATED UNDER FRENCH LAW, TO MANUFACTURE, MARKET, AND LAUNCH FUTURE VEHICLES.

1984 WILL ALSO SEE THE FIRST LAUNCHES OF THE ARIANE 2 AND 3 CLASSES OF VEHICLE, WITH INCREASED PAYLOAD CAPACITY.

IN PARALLEL WITH THE ABOVEMENTIONED ACTIVITIES ESA IS CONTINUING WITH THE DEVELOPMENT OF ARIANE 4 WHICH SHOULD MAKE ITS FIRST FLIGHT EARLY IN 1986, AND IS CARRYING OUT A NUMBER OF STUDIES TO DEFINE THE NEXT GENERATION OF EUROPEAN LAUNCHER.

A SECOND ARIANE LAUNCH FACILITY IN FRENCH GUIANA WILL BECOME AVAILABLE TOWARDS THE END OF 1984, WITH A FIRST OPERATIONAL FLIGHT SCHEDULED IN THE SECOND QUARTER OF 1985; THIS WILL ALLOW A SIGNIFICANT INCREASE IN THE ARIANE LAUNCH FREQUENCY AND PROVIDE ADDED FLEXIBILITY AND REDUNDANCY.

SPACE SCIENCE

IN THE AREA OF SPACE SCIENCE A NUMBER OF PROGRAMMES MERIT MENTION.

ON MAY 26TH 1983 THE EUROPEAN SPACE AGENCY'S EXOSAT SPACECRAFT WAS LAUNCHED FROM THE WESTERN TEST RANGE ON A DELTA 3914 VEHICLE. THE LAUNCH WAS A COMPLETE SUCCESS AND REPRESENTED A RECORD OF SORTS FOR THE DELTA TEAM, IN THAT THEY MET THEIR SHORTEST EVER LAUNCH WINDOW; 1 MINUTE IN DURATION.

EXOSAT IS STILL IN OPERATION AND CONTINUES TO RETURN EXCELLENT DATA.

CO-OPERATION WITH NASA HAS CONTINUED THROUGHOUT THE YEAR IN BOTH THE ISEE PROGRAMME IN WHICH ESA HAS ONE OPERATIONAL SPACE-CRAFT, AND THE INTERNATIONAL ULTRAVIOLET EXPLORER PROGRAMME, IN WHICH ESA HAS CONTRIBUTED THE SOLAR ARRAY AND A GROUND OBSERVATORY. ON MAY 6TH 1983 A TEAM OF EUROPEAN'S WORKING OUT OF THE IUE EUROPEAN GROUND OBSERVATORY AT VILLAFRANCA, SPAIN, USED IUE TO STUDY A NEW COMET NOW CLASSIFIED AS 1983D-IRAS-ARAKI-ALCOCK, WHICH HAD FIRST BEEN DETECTED BY THE IRAS SPACECRAFT ONE MONTH EARLIER.

IN JUNE OF 83 EXOSAT AND IUE WERE BOTH USED TO STUDY A NEWLY DETECTED SUPERNOVA PROVIDING DATA FROM DIFFERENT WAVELENGTHS THE CORRELATION OF WHICH IS EXPECTED TO CONTRIBUTE SIGNIFICANTLY TO A BETTER THEORETICAL UNDERSTANDING OF SUPERNOVAE.

ESA'S HARDWARE CONTRIBUTIONS TO THE HUBBLE SPACE TELESCOPE (SOLAR ARRAYS PLUS ONE OF THE FOCAL PLANE INSTRUMENTS, THE FAINT OBJECT CAMERA) ARE BEING DELIVERED AS PLANNED. SOME REMAINING TECHNICAL PROBLEMS, UNAVOIDABLE IN A PROJECT OF SUCH HIGH SOPHISTICATION ARE BEING JOINTLY DISCUSSED BY THE TWO AGENCIES, IN AN EXCELLENT SPIRIT OF CO-OPERATION. ESA IS CONTRIBUTING TO THE SPACE TELESCOPE PROJECT AT A LEVEL OF ABOUT 15% INCLUDING A TOTAL OF 15 SCIENTISTS ASSIGNED TO THE ST SCIENCE INSTITUTE IN BALTIMORE.

THE ISPM SPACECRAFT DEVELOPMENT HAS BEEN COMPLETED AND THE SPACECRAFT IS PRESENTLY IN STORAGE. CURRENT PLANNING CALLS FOR DELIVERY OF THE SPACECRAFT TO THE US IN EARLY 85, IN PREPARATION FOR A MAY 1986 SHUTTLE LAUNCH. THE SPACECRAFT WILL CARRY EXPERIMENTS FROM BOTH EUROPEAN AND AMERICAN, PRINCIPAL AND CO-INVESTIGATORS.

WORK CONTINUES ON ESA'S GIOTTO SPACECRAFT WHICH IS DUE TO BE LAUNCHED TO HALLEY'S COMET IN JULY 1985. ALL EXPERIMENTS

HAVE EUROPEAN PRINCIPAL INVESTIGATORS, BUT A NUMBER OF US CO-INVESTIGATORS ARE INVOLVED IN THE MISSION.. NASA CONTINUES TO PROVIDE SUPPORT IN THE MISSION ANALYSIS AREA, AND WE WILL USE THE DEEP SPACE NETWORK AS A BACKUP DATA ACQUISITION FACILITY DURING THE ENCOUNTED PHASE WITH THE COMET.

IT IS WORTH NOTING THAT ESA, NASA, ISAS (THE JAPANESE INSTITUTE FOR SPACE SCIENCE) AND IKI (USSR) HAVE JOINED TOGETHER TO FORM THE INTERAGENCY CONSULTATIVE GROUP (IACG) FOR THE EXPLORATION OF HALLEY'S COMET. BOTH IKI AND NASA-JPL ARE ASSISTING ESA IN TARGETING GIOTTO TO APPROACH THE NUCLEUS OF THE COMET AT A DISTANCE OF 500 KM (THE CLOSEST APPROACH OF ALL PLANNED MISSIONS).

DURING THE PAST YEAR ESA'S SCIENCE PROGRAMME COMMITTEE APPROVED THE AGENCY'S LATEST SCIENCE "NEW START" THE INFRA RED SOLAR OBSERVATORY, SCHEDULED FOR LAUNCH IN THE EARLY 90'S, ISO IS SEEN AS THE LOGICAL NEXT GENERATION OF SATELLITE INFRA-RED ASTRONOMY AFTER THE HIGHLY SUCCESSFUL IRAS PROGRAMME. CO-ORDINATION BETWEEN ISO AND NASA'S SIRTF PROGRAMME IS BEING DISCUSSED BY THE TWO AGENCIES.

IN THE AREA OF FUTURE SCIENCE PROJECTS, PLANNING REVIEW MEETINGS ARE BEING HELD ON A REGULAR BASIS, AND JOINT STUDIES ON POTENTIAL FUTURE CO-OPERATIVE VENTURES ARE BEING CARRIED OUT.

THE INTENTION IS TO, WHERE POSSIBLE, CO-ORDINATE PLANNING BETWEEN THE AGENCIES, AND AVOID A WASTEFUL DUPLICATION OF EFFORT.

THE POTENTIAL FOR A PARTICULARLY PROMISING CO-OPERATION IS FORESEEN WITHIN THE FRAMEWORK OF THE INTERNATIONAL SOLAR TERRESTRIAL PHYSICS PROGRAMME. AMERICAN, EUROPEAN AND JAPANESE PARTICIPANTS ARE EACH PLANNING THE LAUNCH OF ONE OR MORE SATELLITES FOR A PROGRAMME OF CO-ORDINATED EXPLORATION OF OUR PLANET'S NEAR ENVIRONMENT, AND HOW IT IS INFLUENCED BY SOLAR AND INTERPLANETARY PHENOMENA.

POTENTIAL CO-OPERATIVE PROJECTS IN PLANETARY SCIENCE AND ASTRONOMY ARE ALSO BEING STUDIED.

DISCUSSIONS ARE CONTINUING BETWEEN ESA AND NASA, AND BETWEEN GROUPS OF US AND EUROPEAN SCIENTISTS, ON THE PRINCIPLES AND MODALITIES OF RECIPROCITY OF FLIGHT OPPORTUNITIES, TO ALLOW THE DIFFERENT SCIENTIFIC COMMUNITIES FLIGHT OPPORTUNITIES ON EACH OTHER PROJECTS. THIS IS CONSIDERED A DELICATE SUBJECT BY ALL PARTIES BUT PROGRESS IS BEING MADE IN A FRANK AND CO-OPERATIVE SPIRIT.

TELECOMMUNICATIONS

OTS AND ECS

IN ORDER TO MEET THE REQUIREMENTS DEFINED BY THE EUROPEAN POSTS AND TELECOMMUNICATIONS AND BROADCASTING ADMINISTRATIONS FOR POINT-TO-POINT COMMUNICATIONS (TELEPHONE, TELEGRAPH, INTRA-EUROPEAN TELEX, EUROVISION PROGRAMMES AND DATA TRANSMISSION), ESA DEVELOPED AN ORBITAL TEST SATELLITE (OTS), LAUNCHED IN MAY 1978.

FOLLOWING THE SUCCESS OF THE PRE-OPERATIONAL SYSTEM, EUROPE DECIDED TO DEVELOP THE EUROPEAN COMMUNICATIONS SATELLITES (ESC), DESIGNED FOR AN OPERATIONAL EUROPEAN REGIONAL SYSTEM, WITH A CAPACITY EQUIVALENT TO 20.000 TELEPHONE CIRCUITS. EACH SATELLITE CAN RELAY EITHER TELEPHONE OR TELEVISION SIGNALS, AND FROM THE SECOND FLIGHT UNIT ONWARDS THE ECS SATELLITES WILL ALSO PROVIDE BUSINESS COMMUNICATIONS (HIGH SPEED DATA TRANSMISSION, INTERCONNECTION OF COMPUTERS ...). ESA WILL PROVIDE UP TO FIVE SATELLITES TO THE EUROPEAN SATELLITE TELECOMMUNICATIONS ORGANISATION, EUTELSAT, DURING THE 1980'S, IN ORDER TO MEET THE REQUIREMENTS OF EUROPEAN USERS. THE FIRST OF THE SERIES ECS-1 WAS SUCCESSFULLY LAUNCHED BY ARIANE ON JUNE 16, 1983. THIS, THE FIRST OPERATIONAL EUROPEAN TELECOMMUNICATION SATELLITE, WAS, ON OCTOBER 12, 1983, FORMALLY ACCEPTED BY EUTELSAT AND CHRISTENED "EUTELSAT-1". THE SECOND FLIGHT UNIT WILL BE LAUNCHED IN 1984, AND THE THIRD IN 1985.

MARECS

THE SATELLITES UNDER THE MARECS PROGRAMME USE A PLATFORM DERIVED FROM THE ECS SPACECRAFT. THEY PROVIDE LONG DISTANCE LINKS BETWEEN SHIPS AND SHORE STATIONS. THE FIRST SATELLITE, MARECS-A, WAS LAUNCHED BY ARIANE IN 1981; THE SECOND, MARECS-B, WILL BE LAUNCHED IN 1984.

THE MARECS SATELLITES ARE A KEY ELEMENT OF A WORLDWIDE SATELLITE SYSTEM TO IMPROVE SHIP-TO-SHORE COMMUNICATIONS. THIS SYSTEM IS OPERATED BY THE NEWLY CREATED WORLD MARITIME COMMUNICATIONS ORGANISATIÓN INMARSAT WHICH LEASES TWO MARECS SATELLITES FROM THE AGENCY.

ESA IS ALSO AT PRESENT STUDYING SATELLITE APPLICATION FOR AERONAUTICAL AND LAND MOBILE SERVICES AND TECHNICAL TESTS AND SYSTEM EVALUATION WILL BE PERFORMED USING MARECS.

OLYMPUS

THE AIMS OF THE OLYMPUS PROGRAMME ARE TO DEVELOP AND TEST IN ORBIT A LARGE PLATFORM, THE FORERUNNER OF A FAMILY OF GEOSTATIONARY SATELLITES, CAPABLE OF CARRYING VARIOUS TELECOMMUNICATIONS PAYLOADS, IN PARTICULAR DIRECT TELEVISION BROADCAST SYSTEMS. THE FIRST OLYMPUS MISSION WILL HAVE A PAYLOAD OF TWO-CHANNEL DIRECT TELEVISION (12 GHZ), A TELECOMMUNICATION PAYLOAD AT 12 GHZ (FOR THE PREPARATION OF THE SECOND GENERATION BUSINESS SERVICES) AND ANOTHER IN THE 20-30 GHZ BANDS TO EVALUATE BOTH

THE TECHNOLOGY AND THE APPLICATIONS OF THESE NEW FREQUENCY BANDS. PROPAGATION EXPERIMENTS WILL ALSO BE PERFORMED IN ALL THESE BANDS. WEIGHTING 1400 KG IN ORBIT, OLYMPUS WILL BE LAUNCHED BY ARIANE IN 1987.

FUTURE TELECOMMUNICATIONS

WORK IS NOW PROCEEDING ON THE DEFINITION OF A FUTURE TELECOMMUNICATIONS PROGRAMME INTENDED TO DEVELOP THE TECHNOLOGY REQUIRED FOR MID-90 TO YEAR 2000 OPERATIONAL TELECOMMUNICATIONS SATELLITE SYSTEM. FOR THIS PURPOSE AN EXPERIMENTAL PREOPERATIONAL SATELLITE MAY BE LAUNCHED AROUND 1990.

NAVSAT

ESA IS CURRENTLY STUDYING A SATELLITE BASED AIRCRAFT NAVIGATION SYSTEM WHICH COULD GRADUALLY REPLACE EXISTING GROUND BASED RADIO NAVIGATION SYSTEMS TO PROVIDE A GLOBAL SERVICE WITH IMPROVED PERFORMANCE AT A LOWER OVERALL COST THAN EXISTING SYSTEMS. THE PRINCIPLE OF USER POSITION DETERMINATION IS SIMILAR TO THAT OF THE US MILITARY GPS.

NAVSAT IS PLANNED AS A PURELY CIVILIAN SYSTEM THAT COULD BE IMPLEMENTED ON AN INTERNATIONAL BASIS.

EARTH OBSERVATIONS

THE CO-OPERATION ON EARTHNET WHICH INVOLVES THE EUROPEAN ACQUISITION OF DATA FROM US REMOTE SENSING SATELLITES, PARTICULARLY THOSE OF THE LANDSAT-PROGRAMME, CONTINUES TO OPERATE SUCCESSFULLY. IN EARLY 83 EARTHNET ACQUIRED SOME 1300 TM SCENES FROM LANDSAT 4. ACQUISITION OF MSS DATA CONTINUES SATISFACTORILY.

WITH THE TRANSFER OF RESPONSIBILITY OF LANDSAT FROM NASA TO NOAA A NEW ESA/NOAA MOU HAS BEEN NEGOTIATED AND HAS NOW BEEN APPROVED BY BOTH PARTIES, AND IS READY FOR SIGNATURE.

ESA'S OCEANOGRAPHIC REMOTE SENSING SATELLITE PROGRAMME, ERS-1, IS CURRENTLY IN A PHASE B EXTENSION WHICH IS SCHEDULED TO BE COMPLETED IN MARCH OF THIS YEAR. A PHASE C/D/E PROPOSAL WAS SUBMITTED TO PARTICIPATING STATES IN DECEMBER 83 WITH APPROVAL BEING SOUGHT IN MID 84. THE PLANNED LAUNCH DATE IS MID 1988.

FRUITFUL DISCUSSIONS ARE TAKING PLACE BETWEEN ESA AND NASA INVOLVING INSTRUMENT DEFINITION, DATA PROCESSING ALGORITHMS AND SUPPORTING STUDIES AND CAMPAIGNS.

A SECOND FLIGHT UNIT OF ERS-1 IS BEING PLANNED FOR LAUNCH 2 TO 3 YEARS AFTER THE INITIAL ONE THUS PROVIDING DATA CONTINUITY OVER A PERIOD OF 5 TO 6 YEARS.

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DEFINITION OF AN ADVANCED LAND MISSION FOR THE EARLY 90'S IS IN PROGRESS, INVOLVING BOTH OPTICAL AND MICROWAVE INSTRUMENTS IN THE PAYLOAD. DEVELOPMENT OF ADVANCED INSTRUMENTATION IS ALSO BEING CONSIDERED FOR FLIGHT ON EURECA II, AN EARTH ORIENTED VERSION OF THE EURECA PLATFORM. THE POSSIBILITY OF FLYING A US INSTRUMENT E.G. THE OCEAN COLOUR INSTRUMENT, IS BEING DISCUSSED.

THE NEXT MULTILATERAL REMOTE SENSING MEETING IS SCHEDULED TO BE HOSTED BY THE USA, IN WASHINGTON, IN JUNE 1984. THESE MEETINGS HAVE, IN THE PAST, PROVIDED A USEFUL FORUM FOR EXCHANGE OF INFORMATION, AND TECHNICAL CO-ORDINATION, BETWEEN OPERATORS OF REMOTE SENSING SATELLITE SYSTEMS.

IN THE AREA OF METEOROLOGY THE OPERATIONAL METEOSAT PROGRAMME IS UNDERWAY AND ESA IS STARTING WORK ON THE SECOND GENERATION OF METEOSAT TO BE LAUNCHED IN THE 90'S. CO-ORDINATION WITH OTHER NATIONS METEOROLOGICAL PROGRAMMES CONTINUES THROUGH THE CGMS.

IN THE FIELD OF GEODESY AND GEODYNAMICS EFFORTS ARE CONCENTRATING ON THE PREPARATION OF A DEDICATED PRECISE POSITIONING SATELLITE MISSION, POPSAT, FOR LAUNCH IN THE EARLY 90'S.

SPACE STATION

AS THE FINAL, AND IN ALL PROBABILITY THE MOST IMPORTANT, TOPIC IN MY TESTIMONY I WOULD NOW LIKE TO ADDRESS THE MATTER OF ESA'S POSSIBLE CO-OPERATION IN THE U.S. SPACE STATION PROGRAMME.

ESA HAS BEEN ENTRUSTED BY ITS MEMBER STATES WITH THE TASK OF STUDYING POSSIBLE OPTIONS IN THE AREA OF SPACE TRANSPORTATION BEYOND SYSTEMS CURRENTLY UNDER DEVELOPMENT (I.E. ARIANE IV, SPACELAB, EURECA), AND OF PREPARING AN OVERALL EUROPEAN LONG-TERM POLICY IN THE SPACE TRANSPORTATION FIELD. IN THE AREA OF ORBITAL SYSTEMS, ONE OPTION INVOLVES PARTICIPATION IN THE PLANNED U.S. SPACE STATION. THE OTHERS ARE MORE INDEPENDENT APPROACHES.

AS REGARDS THE SPACE STATION, WE HAVE EXAMINED HOW OUR CURRENT EXPERTISE COULD BE USED. ALTHOUGH NO FINAL ANSWER EXISTS YET, SPACELAB-DERIVED ELEMENTS LOOK VERY PROMISING AS CANDIDATE COMPONENTS FOR A SPACE STATION. WE BELIEVE THAT SPACELAB COULD BE USED AS A BASIC MODULE WHICH COULD BE "CUSTOMISED" WITH PROPER OUTFITTING TO PROVIDE THE DIFFERENT FUNCTIONS REQUIRED BY A SPACE STATION (HABITAT, LAB MODULE, LOGISTICS MODULE, ETC.). OUR EURECA PLATFORM REPRESENTS ALSO A GOOD CANDIDATE FOR PLATFORMS TO BE SERVICED BY A SPACE STATION.

OF PARTICULAR IMPORTANCE TO EUROPE IN ANY COLLABORATION ON THE SPACE STATION WOULD BE THAT OUR SHARE OF THE WORK WOULD BE SUCH AS TO PROVIDE A STIMULUS TO EUROPEAN TECHNOLOGY.

FURTHERMORE, WHATEVER THE FINAL CHOICES OF HARDWARE, EUROPE WILL WANT TO HAVE A CLEARLY DEFINED ROLE IN THE OPERATIONAL PHASE OF THE SPACE STATION.

ESA WANTS ITS PARTICIPATION TO BE "VISIBLE", THAT IS TO SAY THAT IT WILL AIM AT IDENTIFYING ONE OR MORE ELEMENTS WITH CLEAR INTERFACES, AND OVER WHICH IT WILL EXERCISE FULL RESPONSIBILITY

ON THE BASIS OF ITS COLLABORATION IN THE PROGRAMME ESA WOULD WANT TO HAVE ACCESS TO THE ENTIRE SPACE STATION SYSTEM CAPABILITY AND NOT ONLY TO THE ELEMENT OR ELEMENTS IT MAY POSSIBLY DEVELOP.

AFTER THE SUCCESS OF SPACELAB, EUROPE IS CONSIDERING VERY FAVOURABLY FURTHER INVOLVEMENT IN MANNED SPACE SYSTEMS. HAVING DEMONSTRATED THE QUALITY OF EUROPEAN-MADE MANRATED SPACE HARDWARE AND ITS ABILITY TO MANAGE LARGE CO-OPERATIVE PROGRAMMES, ESA CONSIDERS THAT SOLID GROUNDS EXIST FOR ENTERING ON A PARTNERSHIP BASIS IN THE SPACE STATION DEVELOPMENT.

ESA IS OF THE OPINION THAT ADVANTAGEOUS CONDITIONS FOR BOTH PARTNERS COULD BE FOUND IN THE SPACE STATION DEVELOPMENT AND UTILISATION, AND THEREFORE A SUBSTANTIAL PARTICIPATION OF EUROPE COULD BE ACHIEVED, WHICH WILL ENHANCE THE OVERALL VALUE OF THE SPACE STATION PROGRAMME.

CONCLUSION

IN CONCLUSION MR. CHAIRMAN I WOULD LIKE TO STATE THAT, AS IS EVIDENT BY THE CONTENT OF THIS TESTIMONY, THE AGENCY AND ITS MEMBER STATES CONTINUE TO BE FULLY COMMITTED TO THE CONCEPT OF INTERNATIONAL CO-OPERATION IN SPACE ACTIVITIES, IN PARTICULAR CO-OPERATION WITH THE UNITED STATES.

SUCH CO-OPERATION HAS IN THE PAST YIELDED BENEFITS TO ALL PARTIES INVOLVED, AND IS CERTAIN TO DO SO IN THE FUTURE.

FOR THE AGENCY'S PART WE WILL CONTINUE TO WORK WITH NASA TO FOSTER SUCH CO-OPERATIVE ENDEAVOURS, TO OUR MUTUAL BENEFIT, WHEREVER THE OPPORTUNITY ARISES.

THAT CONCLUDES MY PRESENTATION MR. CHAIRMAN.

Mr. VOLKMER. Thank you very much, Mr. Pryke. We will—I have several questions here. And I first wish to say it appears to me, first, that ESA and NASA have been working together so far very successfully in most of the programs that they work together in.

Mr. PRYKE. That's quite correct. Our cooperation, in fact, goes back over a period of nearly 20 years.

Mr. VOLKMER. And noting in the communications area that you're going further and further into that, not only voice, TV, and data——

Mr. PRYKE. That's correct.

Mr. VOLKMER [continuing]. Computer outbursts, et cetera. Are you getting into the 30/20 gigahertz field?

Mr. PRYKE. The L-Sat program, now currently known as Olympus, under which we are developing a large telecommunications satellite to serve foreseen needs through the rest of this decade and beyond, will, in fact, fly on its first mission a payload being developed by the European Space Agency. Two elements of that payload involve 30/20 gigahertz technology. One is data transmission, and the other is a beacon experiment to study the effects of atmospheric attenuation and such like in that frequency band. The payload will also include a direct broadcast TV experimental/preoperational system.

Mr. VOLKMER. Now are you familiar with our ACTS program that we have?

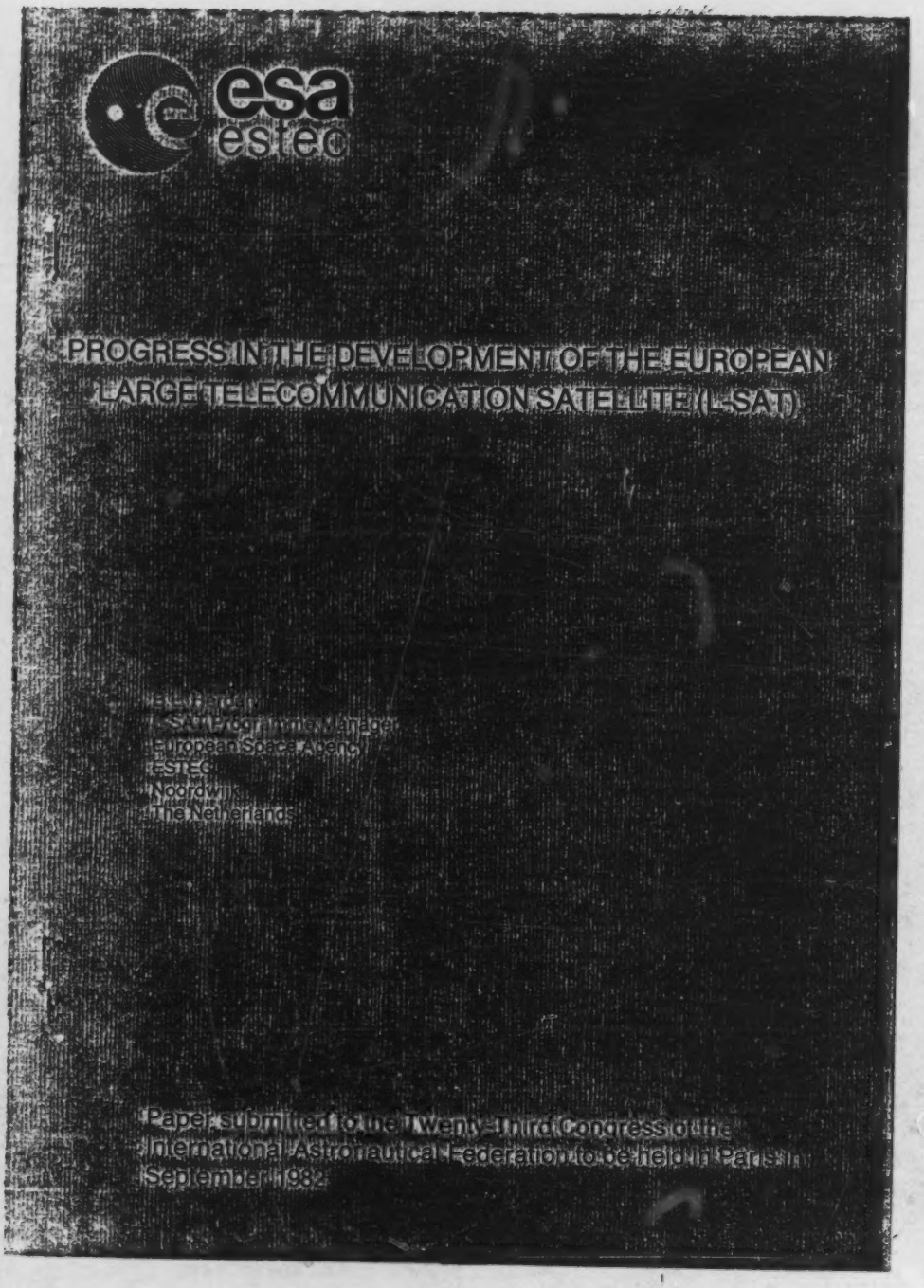
Mr. PRYKE. Moderately, yes. I try to follow it.

Mr. VOLKMER. Well, there we have the processing and the switching problems that we're trying to work out, the time division, the multiple access—in other words, to more highly utilize the transponders, et cetera. Are you all looking into that area, also?

Mr. PRYKE. I must confess to not being thoroughly familiar with the full content of the 30/20 gigahertz payload and exactly what we're doing with it. I will, however, provide details for the subcommittee.

Mr. VOLKMER. I appreciate it.

[The information follows:]



PROGRESS IN THE DEVELOPMENT OF THE EUROPEAN LARGE TELECOMMUNICATION SATELLITE (L-SAT)

E.L. Bartolini
L-SAT Programme Manager
European Space Agency
ESTEC
Noordwijk
The Netherlands

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PROGRESS IN THE DEVELOPMENT OF THE EUROPEAN LARGE TELECOMMUNICATION SATELLITE (L-SAT)

B. L. Herdan
L-SAT Programme Manager
European Space Agency
ESTEC, Noordwijk, The Netherlands

Abstract

The development of the European Large Telecommunication Satellite (L-SAT) commenced in December 1981. After a brief outline of the programme objectives and the satellite characteristics, the development plan is outlined and the current status of the main activities is given. Planning for the in-orbit utilisation of the four L-SAT 1 communications payloads is described. The paper concludes with a summary of recent work on four typical L-SAT derivatives adapted to a wide range of potential applications in the fields of direct-to-home television broadcast, communications with mobiles, regional fixed service telecommunications, and earth observations.

1. Introduction

The L-SAT development programme was approved by the participating governments in December 1981 following a two year definition phase. The paper starts with a brief recapitulation of the programme scope and objectives and an outline of the satellite design. Thereafter, three main themes are covered, namely :-

- the plans for the satellite development and the current status of the work with emphasis on key technological elements,
- the planning for in-orbit operation and test of the satellite and for utilisation of the four communications payloads,
- the results of studies undertaken within the last year on four typical L-SAT derivatives with a fair chance of eventual realization.

2. Programme Scope and Objectives

The origins of the programme date back to 1979 and the decision within the ESA framework to undertake a wide-ranging study whose objectives were to take stock of the future market prospects for telecommunication satellites of European origin and hence to derive the correct orientations for any near term development programmes to be sponsored by the Agency in this domain. It was on the basis of the positive results of this study that the decision was taken to proceed with the L-SAT definition phase. The studies demonstrated that larger and more powerful satellites will be needed to meet many of the foreseen requirements over the next 10-15 years in a cost effective manner, and that a competitive satellite product could achieve a substantial number of sales over that period. Against the above background the L-SAT programme objectives were established as follows :

- development and in-orbit demonstration of a large multipurpose platform able to satisfy the range of foreseen future mission requirements on a cost-competitive basis,
- development of communications payload hardware related to future mission needs and in-orbit demonstration of new types of satellite communications system by a multi-element payload conceived to stimulate the new services and applications.

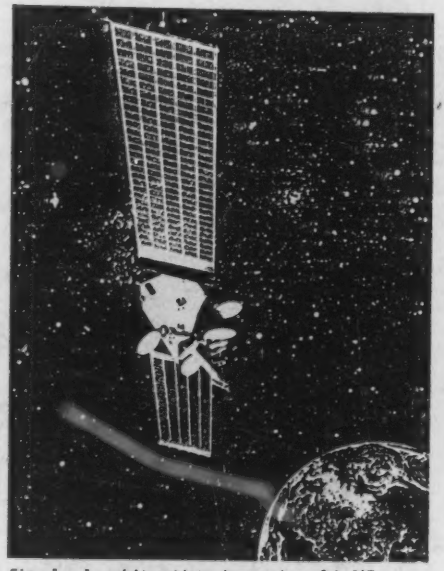


Fig. 1 In orbit artists impression of L-SAT

The content of the approved L-SAT programme includes the following main elements :-

- development of the platform and of four communications payload elements,
- manufacture, integration and test of a single flight model satellite together with the hardware needed to construct a second flight model with minimum delay in case of a first launch failure,
- procurement of an Ariane 3 launch vehicle and launch,
- development of the ground segment for satellite operation, and operations over a period of at least five years,
- coordination of satellite utilisation and deployment of limited ground facilities by ESA for satellite tests and demonstrations,
- ESA programme management and supporting studies.

The total budget for the programme is around

$490 million expressed at 1981 price levels and this bill will be shared by the participating countries : United Kingdom, Italy, Canada, Netherlands, Belgium, Spain, Denmark and Austria.

3. Satellite Design Characteristics

To meet the first of the two programme objectives, a platform design has been elaborated which is driven not by the requirements of the first demonstration payload but by the predicted needs of future payloads defined in terms of :-

- payload mass, power consumption and thermal dissipation,
- payload layout requirements in terms of mounting area, mass distribution and accommodation of antennas,
- antenna deployment and pointing accuracy requirements.

The L-SAT design is to be fully compatible with the European expendable launch vehicle (ARIANE) and with the US Space Transportation System (STS) combined with various perigee stage options. The platform is to be of a modular design and will have long in-orbit design lifetime to improve the operating economics of derived operational systems. Emphasis has been put at every stage of the platform definition on the achievement of a low recurring price, both through the selected design and through the selection by price competition of the most attractive procurement sources at equipment level.

To meet the second of the two overall objectives, it was decided to elaborate a multiple payload for the first "demonstration" L-SAT 1 flight opportunity. Four payload elements have been selected on the basis of relevance to the user community needs, applicability of payload technology developments to the needs of future operational missions, mutual compatibility of payloads, and compatibility with a single orbit slot :

- a payload to support direct broadcast in view of the strong market prospects in this domain, the need to acquire and demonstrate certain new technologies to satisfy future requirements;
- a payload for specialised or business services in the European zone, to develop certain new technologies of relevance to the next generation systems and to demonstrate current and new applications;
- a payload consisting of transparent 20/30 GHz transponders to demonstrate systems expected to operate in this band and to develop the necessary technological elements which will be needed as "building blocks" in more complex operational systems.
- a payload consisting of beacon generators at the 12 GHz, 20 GHz and 30 GHz frequencies to support the collection of propagation data.

The modular satellite configuration, the main features of the platform, and the accommodation of the four L-SAT 1 communications payloads are all illustrated in the exploded view of Figure 2.

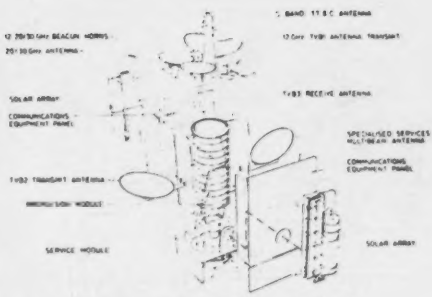


Fig. 2 Exploded view of L-SAT

Table 1 summarises the main features of the L-SAT 1 configuration and also indicates the inbuilt satellite growth capability as applicable. More details are given in reference 1.

PARAMETER	L-SAT 1 CONFIGURATION	GROWTH CAPABILITY
Satellite Lift-off Mass (Kgs)	Payload 304 Platform 823 Fuel 1176 Margin 127 Total 2430	Payload mass up to 600 Kgs depending on power demand. Total lift-off mass up to 3500 Kgs depending on launch trajectory.
DC Power (Watts-Equinox-End of Life)	Payload 2225 Platform 870 (incl. Battery Recharge) Margin 340 Array Capability 3435 Eclipse Capability 990	Power up to 6500W sunlight only, and 4000W sun and eclipse.
Dimensions (Metres)	Body 2.1 x 1.75 x 5.5 Array Span 26.3	Body size to remain fixed. Array span up to 48 metres.
Lifetime, Orbit location	5 years minimum 19° W	10 years "
Payload Content	8 redundant transponders and 3 beacons. 9 antennas (5 steerable)	Growth versions analysed with up to 50 transponders. Extreme flexibility for multiple antenna accommodation
Antenna Pointing Accuracy	0.2° body pointing accuracy. 0.1° with RF sensing and closed-loop antenna pointing.	Same Note ability to operate with or without RF sensing systems.
Launch Vehicle	Baseline is Ariane 3. (STS launch option)	Compatible with Ariane 3 Ariane 4 STS

TABLE 1 : MAIN L-SAT CHARACTERISTICS

4. Development Plans and Progress Report

The satellite development programme starts with equipment detailed design activities and generation of drawings and circuit diagrams, followed by breadboarding of new equipments - indeed the programme was preceded by some predevelopment work during the definition phase. Ordering of all long lead parts and materials must also start as soon as equipment design is adequately advanced. Once this type of early programme activity is complete, qualification model equipment manufacture and test can be progressively released as can the (largely parallel) manufacture and test of the three main spacecraft-level development models and some other lower level development models as listed below.

Structure Model

The structure model is used for

. Static testing on the primary structure to prove the basic structural integrity,

. Modal survey testing at dynamic test standard, less appendages to prove the mathematical model,

. Dynamic testing when fully equipped with appendages, followed by mass properties and physical measurements.

Thermal Model

The thermal model is used for

. Solar simulation testing to verify the thermal mathematical model;

. Infrared (IR) testing to correlate IR tests results with solar simulation and prove procedures for use of IR testing on subsequent flight spacecraft.

Electrical Integration Model

The electrical integration model is used for

. Integration of engineering model equipments to prove procedures for flight;

. Electrical compatibility testing including EMC tests.

Development Models below Spacecraft Level

. Propulsion system : A development model of the propulsion system is built and used for flow and expulsion tests;

. Solar Array : A development model wing is built and tested before being integrated for dynamic testing at system level;

. North/South heat pipe radiators : Structure and thermal models of the communications module radiators are built and tested at sub-assembly level;

. Payload elements : Engineering models of the payload elements are integrated and tested independently before being integrated into the spacecraft and an overall payload test at EM level is performed before delivery for spacecraft level tests;

. Subsystem Level Bench Test Models : For power, TT & C and AOCS it is planned to perform bench level AI & T using the EM units of the subsystems prior to delivery to the electrical integration model spacecraft. It is also planned to conduct air-bearing dynamic tests on the AOCS.

The current programme planning, leading to a launch in the first half of 1986 of the protoflight model after its full series of qualification and acceptance tests, is outlined in the barchart of Figure 3.

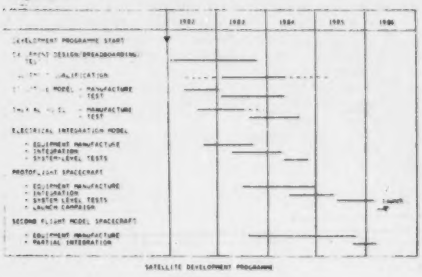


Figure 3

Current Programme Status

With the completion of the satellite definition phase and certain supplementary tasks during the first months of the development phase, the satellite design has been effectively finalised at system and subsystem level. A Baseline Design Review was conducted during the spring and early summer of this year to reach agreement on the design baseline for the start of development. A full-scale satellite mockup has been constructed (Figure 4) which shows the layout and geometry. Parts and materials listings are being finalised and orders are currently being placed for long lead items, certain special parts also being subject to evaluation and qualification programmes. The satellite electrical checkout equipment and mechanical handling equipment is under construction with long lead items such as computers having already been delivered early this year.

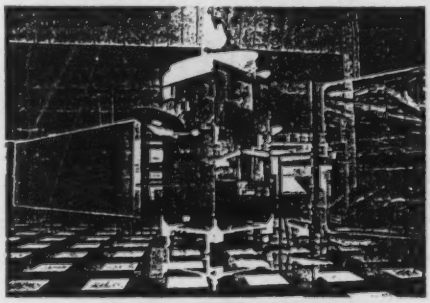


Fig. 4 L-SAT Full Scale Mock Up

Moving on to the platform subsystems, the following details of current progress can be given on a subsystem-by-subsystem basis.

Structure

Work has started on the fabrication of the structure model. Development samples of special elements of the structure design have been built and tested. In parallel, the structure mathematical model has been updated and re-run to verify the expected environmental levels and coupled analyses have been performed with both candidate launch vehicles to ensure satellite/launch vehicle interfaces are correct. First tests on the complete structure model should start in Spring 1983.

Thermal

In parallel with the running of the thermal mathematical model to predict in-flight equipment temperatures and optimize the thermal design, a full-scale development model radiator has been built and is currently under test with the objective of verifying technologies and processes. The radiator consists of a typical assembly of heat pipes, doublers and spreaders, with simulated heat sources, and is extensively instrumented to ensure detailed verification of performance. The complete spacecraft thermal model is scheduled for completion of build by the end of 1983.

Propulsion

While most of the equipments comprising the

combined propulsion subsystem are existing designs (See Figures 5 and 6 for example), development tests are being conducted to prove the construction techniques for the associated pipework and manifolds interconnecting the tanks and engines. In addition, construction is nearing completion of a major new facility to assembly and test the combined propulsion subsystem. The development model is expected to commence its test programme in late 1983.

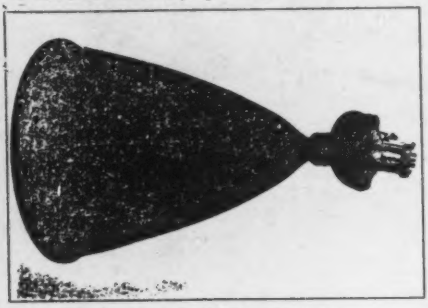
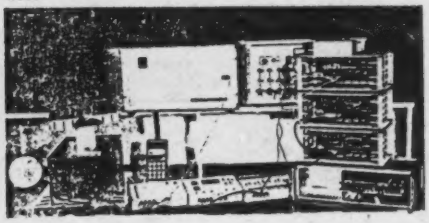


Fig. 5 Marquardt 400N Bipropellant Apogee Engine

Fig. 6 Marquardt 22N Bipropellant Thruster

AOCS

While emphasis has been placed on fully proving the AOCS microprocessor-based central processor by extensive breadboarding and test, other hardware orientated activities have also been completed on the gyros, reaction wheels, and solar array drive mechanism. Continuous updating of the simulations on dynamics performance in the various operating modes of the AOCS has been performed. Integration and test of the engineering model of the AOCS subsystem is expected to commence in late 1983, Figure 7 shows the development testbed for the AOCS electronics system which is currently intensively utilised.



Solar Array

The L-SAT solar array represents a particularly challenging development of a system incorporating the latest technology to achieve attractive power : mass ratios at higher power levels. At this stage, work is in progress on several elements. The development model of the tip tensionning mechanism has been built and is currently under test. A representative stowed blanket pack is undergoing mechanical testing, while a full scale model of the blanket has been developed to assist in optimising the configuration of the parking springs. Early test samples of the primary hold-down points have been built, mainly to verify surface finish properties and wear characteristics. Work will start soon on the manufacture of the complete development model array. Figure 8 shows the array design in schematic form.

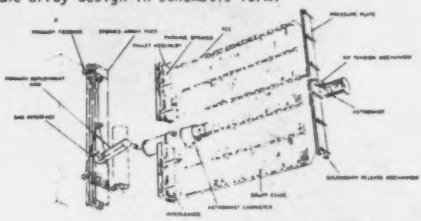


Fig. 8 Solar Array

Power Conditioning

Breadboarding of all critical parts of the power subsystem equipments is in progress. A complete model of the power collection and distribution ring has been built and has been used to optimize the method of connecting the power lines to the ring and the design of the unit itself.

TTC

Extensive development work on the data handling bus and the remote control cores, which perform the interface function between the centralized data handling system and its distributed users, has been completed. Improved test facilities have been built at INTA (Madrid) to measure the performance, on a full scale model of the spacecraft, of the TTC S-band antenna. This work is supported by detailed mathematical modeling of the predicted antenna pattern, in particular to determine any influences introduced by the deployed solar array or by the payload antennas.

Concerning the payloads, the following summarises the current progress or work on each of the four payload elements.

Broadcast Payload

For the technologically demanding antenna conforming to the WARC specification for the Italian beam, the feed system has been breadboarded and work is now in hand to manufacture a complete electrical model for full characterisation tests. A flight-representative antenna pointing mechanism is being manufactured for use in a life test programme. The high power (230 watt) travelling wave tube amplifier (TWTA) is also a critical equipment and work on the tube (TWT) and power conditioner (EPC) have

been underway for several years. Tests employing a breadboard TWT and coupled to an engineering model EPC have started recently and results to date are promising. The EPC is also currently undergoing a prequalification test programme. For all other active elements of this payload (receiver, channel amplifier, high power switch etc) it can be reported that breadboarding work is underway. Figure 9, 10 and 11 show breadboards or engineering models of three of the equipments mentioned above.

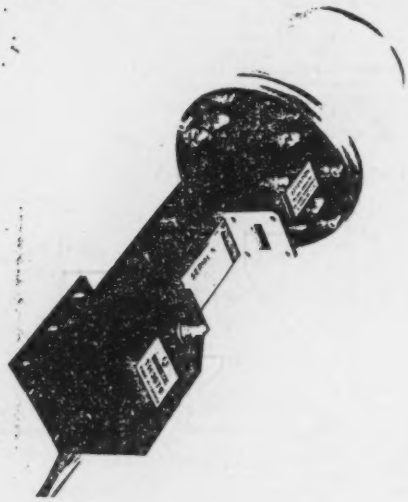


Fig. 9 Travelling Wave Tube

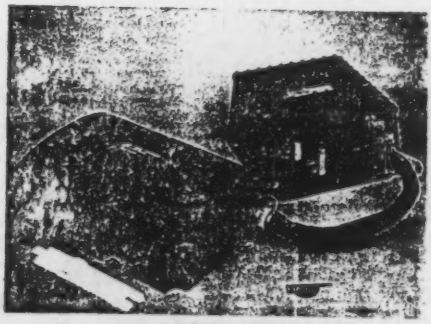


Fig. 10 EPC

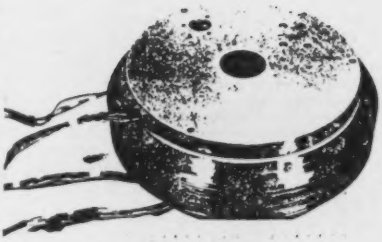


Fig. 11 Antenna Pointing Mechanism

Specialised Services Payload

The two most challenging equipments in this payload are the multibeam antenna and the 1 GHz switching matrix. Tests on a breadboard of the antenna have been satisfactorily completed, and the breadboard switching matrix should be ready for test by mid summer. All other active equipment are currently being breadboarded.

20/30 GHz Communications Payload

Hardware work on the 30 GHz parametric amplifier receiver has been underway for some time and a complete breadboard should be available by early autumn. A breadboard of the complete 20 GHz TWTA will also be ready for test in the autumn and this will mark an important milestone for this payload. Other hardware is also being breadboarded at time of writing.

Propagation Beacon Payload

All active elements of this payload are currently being breadboarded, special attention again being devoted to the 20 GHz and 30 GHz TWTA's.

5. Planning of In Orbit Test, Demonstration, and Utilisation Programmes

The orbiting of the four L-SAT payloads will offer the user community and the Agency a wide and varied range of possibilities for tests, demonstrations and provision of services. The L-SAT utilisation programme is being constructed in close collaboration with the user community and can be expected to incorporate the following types of activity :-

(a) evaluation of the satellite performance in orbit through periodic routine and special measurements, derivation of results with relevance to future satellite design considering both platform and payload aspects;

(b) experiments, test and measurement campaigns in the domain of telecommunications systems, with the broad aim of obtaining data and experience relevant to the design of future system;

(c) demonstration of new satellite-based communications and broadcast systems and applications with the general aim of promoting European products and communications services;

(d) operation of pilot services with a view to preparing for the introduction of foreseen operational services;

(e) possible operation of services on a revenue earning basis, albeit generally without the security of an in-orbit spare satellite for back-up, unless L-SAT 1 is itself being employed as part of a two satellite system.

The European Space Agency has the current responsibility for preparation of the test and utilisation programme in collaboration with users. The following summarises current planning with some emphasis on the broadcast applications.

Broadcast Payload Utilisation

Th broadcast payload consists of two channels with a common receiver and a common receive antenna with European coverage. The first channel is intended to be used for a pre-operational service of TV direct broadcast in Italy and is designed in compliance with the plan established by WARC-77 for that country. The second channel is intended for experimental use by all active members of the European Broadcasting Union (EBU) and its antenna beam can therefore be steered towards any European country. An example of the coverage provided by the combined beams is shown in Figure 12.

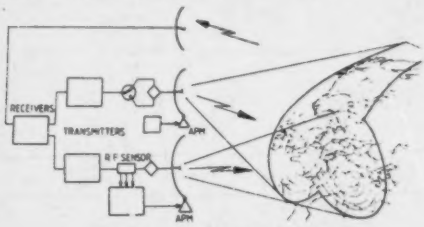


Fig. 12 Broadcast Payload

A special group formed by members of the E.B.U., RAI (Italian broadcasting organisation) and ESA is preparing a general utilisation plan, while a specialist group of the E.B.U. subgroup R3 has been requested to prepare the planning for technical tests. Letters have already been exchanged, between the President of the E.B.U. and the Director General of ESA which underline the joint interest in this project. Against this background the following demonstration programmes stand out :

European Technical Experiments

Technical experiments and tests will be coordinated through the EBU specialist group and will likely include the assessment of satellite performances specific to satellite broadcasting. Special test equipment will often be needed and several transmit and receive stations will have to cooperate.

National Broadcast Experiments

National experiments will be conducted on a time-sharing basis and by re-pointing the European channel to the specific coverage areas on a pre-arranged schedule. The responsibility of such experiments will be with the organisation performing them, so will be the provision of the necessary facilities.

The European Programme Experiments

A great interest has been expressed in a regular joint European programme. This can be readily transmitted over practically all of Europe by combining the two L-SAT broadcast channels. The current utilisation planning, as envisaged by the E.B.U./RAI/ESA group, reserves a good proportion of the time for such an interesting experiment. The programme reception will rely on the availability of 12 GHz receivers to the public. At least 10 million households in 1986 will be connected to cable networks and these are likely to distribute satellite programmes from very early on. Many others will have individual or community receivers.

Feeder Link Experiments

The operating systems to be employed for uplinks to broadcast satellites have yet to be optimised. The L-SAT launch will provide an opportunity to experiment with techniques such as uplink power control and diversity operation, and also to explore the potential for use of small stations for outside broadcast applications.

Experimentation with Advanced Broadcast Systems

There are several advanced systems under consideration ranging from multiple sound channels in digital transmission to high definition television. Field tests of some of them will allow a proper assessment of the performance but may also enable some early conclusions about the acceptance of such new systems by the general public.

This preliminary discussion of L-SAT broadcast demonstrations already illuminates the wide application this payload will find and many more ideas will certainly arise. In most cases broadcasting organisations will take the initiative and will have available their own equipment. They will also be clearly responsible for provision of TV programmes where relevant. However, there may also be cases where a feeder link to a satellite is needed but a station will not be available. In such instances access to the satellite can best be achieved through the provision of a transportable transmitting station which will be arranged by the Agency.

Specialised Services Payload Utilisation

Specialised services (also called business services) will first be implemented in Europe with the second flight unit of the ECS series and the French Telecom-1 satellite. Because of its more extended coverage, the ECS system will necessitate the use of larger stations than Telecom-1 since both types of satellites use a single beam. Eventually the dilemma "wide coverage or small stations" will be eliminated by the introduction of satellites using a cluster of narrow spotbeams associated with an on-board switching matrix working in the SS-TDMA mode to route signals, burst by burst, between the different beams. The Specialised Services payload of L-SAT was conceived as a prototype for such an advanced second-generation business system for Europe. It consists of four receivers and four transmitters which can be coupled to four of the five available beams. Figure 13 shows the payload concept and typical coverage of Europe.

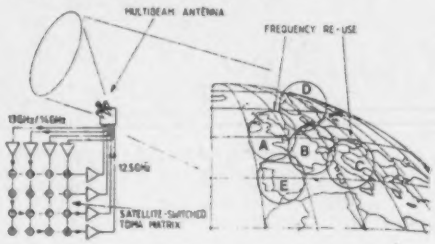


Fig. 13 Specialised Services Payload

The proposed programme of experiments includes:

- SSTDMA operation,
- Frequency re-use by spotbeam separation,
- Frequency re-use by polarisation separation.

In addition to this aspect of the mission, the payload can be configured to provide facilities for "simpler" communications such as television transmission to small dishes (e.g. for cable stations) and multi-point videoconference. The complete antenna can be steered to any part of the globe visible to perform demonstration in Africa and South America. ESA plans to provide some minimal ground segment elements for tests with this payload too, concentrating on technical evaluations and videoconference applications where portable facilities are foreseen.

20/30 GHz Communications Payload Utilisation

The 20/30 GHz Communications Payload has been conceived as a multi-purpose, flexible two-channel repeater with switchable bandwidth and steerable coverage, in consultation with a wide range of potential users. The configuration is illustrated in Figure 14.

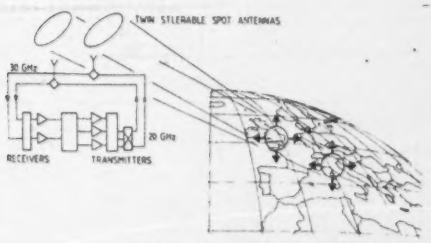


Fig. 14 20/30 GHz Communication Payload

The following experiments have been proposed :

- Point-to-point Video Teleconference,
- Multi-point Video Teleconference,
- Wideband Transmission Experiments,
- Tele-Education,
- Frequency Re-use by Spot-Beam Separation,
- Intersatellite link tests with the Retrievable Carrier free-flying satellite.

Some of these experiments are of specific interest to certain users only but others have generated a much wider spread of interest. The video teleconference experiments in particular are of immediate interest to different parties because of the relevance of the service as a replacement for travel once it becomes convenient and economically attractive, because of the strong possibility that video teleconference may demand large numbers of high-capacity satellites, and because of the wide variety of system and hardware problems which must be solved. The payload consists of two receivers and three transmitters which can be connected to two independently steerable spotbeam antennas in a variety of configurations.

The Agency plans to construct two transportable earth stations and videoconference facilities to promote the utilisation of this payload. It should be mentioned that for this particular payload, active consideration is being given to a utilisation programme in Canada as well as in Europe, a possibility facilitated by the flexible payload configuration and of interest to the Canadian authorities in view of their current plans for exploitation of frequency bands at 20 GHz and above.

Propagation Payload Utilisation

The effects of the weather on the behaviour of radio signals are very important elements to take into consideration in the design of a satellite communications system, particularly at frequencies as high as 20/30 GHz. An early start in the investigation of these phenomena is therefore essential if one wishes to be in possession of sufficient information by the time the design work begins on a particular system. The beacon package of L-SAT (Figure 15) provides the possibility of making direct measurements all over the European region. The three beacon signals are provided, the 12 GHz signal being intended to serve as a reference with which the other two can be compared. The 20 GHz signal can have its polarisation switched between linear vertical and linear horizontal, while the other two signals remain vertically polarised. By measurement the signals received from this set of beacons, it will be possible to characterise the atmosphere completely from the propagation point of view. The design of this payload has been based on extensive discussions with future users and on experience gathered in Europe with OTS and NASA's ATS 6. Receivers will be relatively inexpensive for individual users.

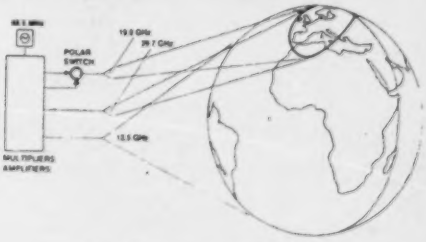


Fig. 15 Propagation Payload

6. Future L-SAT Derivative Spacecraft

As explained at the beginning of this paper, the objectives of the L-SAT programme are strongly oriented towards preparation for future commercial derivative programmes and the satellite definition has been performed with this in mind as a high priority. Various typical derivative programmes were envisaged at the start of the definition phase and the necessary analyses were made during the execution of the satellite definition activities to ensure continuing compatibility between the L-SAT platform design and the anticipated mission requirements for these foreseen derivative programmes. The L-SAT analysis and test programme is intended to verify the practical achievement of the various platform growth requirements. Four possible future missions leading to requirements for L-SAT derivatives have been subject to recent analysis by the Agency and/or British Aerospace (the Prime Contractor); the following summarises the assumed typical mission features and resulting L-SAT derivative satellite parameters for these four examples.

Two Country Direct Broadcast Mission

The L-SAT platform has in part being conceived with a view to meeting market requirements for direct-to-home TV broadcast applications - indeed as mentioned earlier there will be an important demonstration of the L-SAT capabilities in this domain with the first L-SAT launch. The evolution of direct broadcast in Europe is not easy to predict. Early satellites are likely to be of limited capacity (2 or 3 channels) and may not reach the L-SAT class in some cases. However the L-SAT class satellite will come into its own where a country combines a moderate broadcast capacity with substantial fixed services capacity, where a larger number of broadcast channels of higher power are implemented for one country, or where two countries decide to share a common platform in order to save costs in the areas of the space segment, launch and operations.

As an example of the latter, an L-SAT derivative has been elaborated to meet the requirements of two typical European countries - one with larger, one with smaller territorial area. Two fully redundant channels are provided for the former equipped with 230 watt TWTA's, while three fully redundant 100w channels are provided for the latter. This leads to a payload mass of about 250 Kgs, a payload power demand of about 2 Kw, and accommodation of two antennas matched to the two coverage areas. The overall satellite would need a 3.2 Kw solar array and would be compatible with an Ariane launch when loaded with 10 years of propellant, also allowing for limited eclipse operation. The in orbit configuration is shown diagramatically in Figure 16.

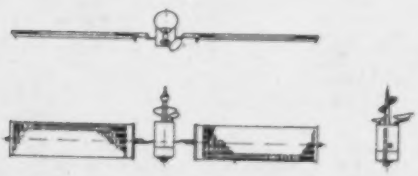


Fig. 16 L-SAT Derivative : Two Country Broadcast Mission

Multiple Mobile Services Demonstration Mission

Several potential application exist for L-SAT derivatives in the field of satellite-based mobile communications systems, particularly where the capacity requirements grow to meet the needs of integrated systems for land, sea, and aeronautical mobiles in the civil and/or military field. One example of such an integrated mission which has been the subject of recent and indeed continuing work is a Canadian operational national mobile services system and its precusor, the demonstration satellite M-SAT. The Canadian government is currently considering the development of M-SAT to develop the market, support necessary technology developments in its industry, and prepare the ground for a subsequent operational service. Although not yet finalised, it is currently envisaged that four payloads may be embarked on M-SAT, namely

- low UHF payload for data relay and search and rescue uplinks, utilising SHF backhaul;
- a high UHF payload for up and down link mobile services, also utilising SHF backhaul;
- an SHF payload for the above mentioned backhaul functions;
- an EHF experimental package.

The compatibility of the L-SAT platform with the accommodation of these four payloads has been demonstrated and definition phase work is currently underway. Two very large (10 metre) unfurlable antennas are required and the payload mass totals around 225 Kgs. The DC power demand is relatively low with the total required array output being around 2.2 Kw - however the deployed array length is high since the inner section is to be free of solar cells to avoid shadowing by the antennas. The satellite liftoff mass of about 250 Kgs is compatible with Ariane 3 or the STS/Perigee stage equivalent. Figure 17 shows the configuration of this derivative.

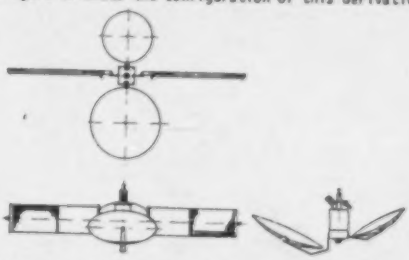


Fig. 17 L-SAT Derivative : Canadian M-SAT Mission

European Fixed Service Telecommunications Mission

The first generation Eutelsat system based on the ESA ECS satellite series is about to be deployed and will need to satisfy a wide range of European mission requirements in the fields of trunk telephony (the originally foreseen application), relay of TV programmes, and specialised or business services. Eutelsat currently predicts that it will need a new generation of satellites by 1990. It is impossible in fact to forecast with any degree of certainty how the traffic over the network will develop during the first years since there is not yet the beginning of a trend from which to extrapolate. However, if one goes by the experience gathered with other satellite networks in the world, one can expect that the well recognised advantages of satellite links will soon pay dividends and that the utilisation factor will increase faster than predicted. In any event, the second generation of satellites for Eutelsat will required to offer a substantial increase in traffic capacity which will be obtained by either expanding the service into the new frequency bands allocated by WARC-79, or by re-using further the same frequency bands through multiple spot beams. It is not yet clear whether a common satellite will be employed for all services or whether the telephony and specialised services traffic will be accommodated by separate satellites. The decision on this question will depend on many factors including traffic growth predictions and the various frequency plan constraints. It is stressed that the requirements for the next generation will in any case originate from Eutelsat based

on the inputs from the European PTT's.

Meanwhile, several possible configurations of L-SAT derivatives have been studied to meet the eventual requirements of either a dual service satellite system (telephony + specialised services) or of two separate service satellite types. Assuming a configuration similar to the current ECS satellite to meet the dual service mission, with eight antennas with full European/spotbeam coverage (single beam per antenna), about 40 channels with adequate redundancy could be accommodated by an L-SAT derivative satellite launched by one of the Ariane 4 variants. This satellite would employ polarisation reuse and also some frequency reuse, would need an array of about 4 Kw capability and adequate battery capacity for full sunlight and eclipse operation, and would carry a payload of some 430 Kgs leading to a total satellite mass of the order of 3300 Kgs in transfer orbit. Alternatively, the same satellite type - eventually with somewhat less capacity and lower mass - could be employed for telephony and a second satellite type could be developed with features more precisely tailored to the needs of the specialised service mission. The configuration for such a satellite based on use of the L-SAT platform has also been studied. Three antennas could be employed to generate a contiguous multiple spotbeam coverage of Europe and the repeater configuration could be similar to the L-SAT 1 equivalent payload with a switch matrix for satellite-switched TDMA operation but, of course, many more transponders. Again assuming for example an Ariane 4 launch, some 24 channels could be accommodated and the overall satellite mass and power parameters would be similar to those given above. Figure 18 illustrates the configuration for such a spacecraft.

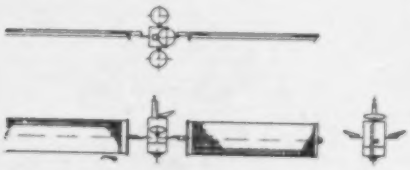


Fig. 18 L-SAT Derivative :
European Fixed Service Telecommunications

arth Resources Mission

During the L-SAT definition phase, little ns:leration was given to non-telecommunications issions other than in allied field such as data elay and dissemination. However, more recently, ie possibility of reuse of the L-SAT platform - its constituent elements - for low earth orbit irth resources mission has received some tention. A study is currently underway to amine the possible applicability of the L-SAT atform to a Canadian application in the Radarsat rogramme. The primary objective of this programme the surveillance and imaging of ice around e Northern coasts of Canada and identification objects down to 30 metre dimensions. Secondary jectives are to provide information on renewable sources, non-renewable sources, and oceans. The envisaged primary payload is a synthetic aperture radar (SAR) employing planar array or reflector, and secondary payloads under recent consideration have included a microwave scatterometer and a thematic mapper, the weight of preference being for the former. The compatibility of the L-SAT platform with such a mission has been established in rather broad terms and work is now underway to establish the situation more precisely. The accommodation of the payload represents something of a challenge, particularly in view of the SAR antenna dimensions : Figure 19 shows one possible configuration now under evaluation. The satellite mass at launch would be around 3500 Kgs.

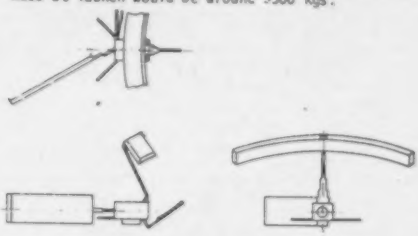


Fig. 19 L-SAT Derivative : Low Earth Orbit Mission

7. Conclusions

The L-SAT programme has just entered its development phase which is expected to culminate in 1986 with the launch of a demonstration satellite. The early development work is underway and progress to date is satisfactory. The four payloads of L-SAT 1 will allow a wide community of potential satellite users to experiment with different kinds of new services and techniques. The utilisation programme which is now in the process of being defined will take account of their wishes and requirements to the largest possible extent. As far as the future is concerned, there exists a whole range of applications which will require spacecraft of the L-SAT type, either to support the expansion of conventional services already provided by satellite or to introduce new services for which there exist an important market. Four examples of promising, relatively near term, potential applications have been described and some information has been given on the respective L-SAT derivative satellite configurations. Work will continue both on these applications and on others, and priority will meanwhile be placed on the successful implementation of the L-SAT development programme on which the derivative missions will rely.

Acknowledgements

A number of colleagues have contributed to this paper including Messrs Fromm, Dinwiddy, Bartholomé, Bonhomme, Steels, Dickinson and Atkinson. Their assistance is gratefully acknowledged.

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PAYLOAD TECHNOLOGY FOR THE EUROPEAN LARGE TELECOMMUNICATION SATELLITE (L-SAT)

R. Bonhomme, W. Greiner, N. Neale
European Space Agency
ESTEC
Noordwijk
The Netherlands

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On Communications to be held in Boston in June 1983.

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PAYLOAD TECHNOLOGY FOR THE EUROPEAN LARGE TELECOMMUNICATIONS SATELLITE (L-SAT)

R. Bonhomme, W. Greiner, N. Neale

European Space Agency, ESTEC

ABSTRACT

The European Large Telecommunications Satellite (L-SAT), to be launched in 1986, will carry four telecommunication payloads, operating at frequencies ranging from 12 GHz to 30 GHz. A description is provided for each payload element. Some technological features are described for antennas, receivers and power amplifiers. Early test results of some advanced technology equipments are presented.

INTRODUCTION

In the frame of the European Space Agency (ESA) Telecommunications programme, the full scale development of the European Large Telecommunications Satellite (L-SAT) started in December 1982, with the view of a launch date in early 1986 (Ref. 1). The industrial team involved in the L-SAT project includes the following European firms : British Aerospace as Prime Contractor, Selenia as payload main contractor, Bell Telephone Manufacturing (BTM) and Marconi Space & Defence Systems (MSDS) as payload subcontractors.

The paper starts with an overview of the major events in the European Payload technology at 12/14 GHz, which preceeded the start of the L-SAT programme. The paper provides thereafter :

- a summary of the characteristics of the four L-SAT payload elements and their main design features.
- a design and technology description of some keys technological payload items operating in the Ku and Ka frequency bands namely antennas, low noise receivers and travelling wave tube amplifiers (TWTA).

TECHNOLOGY PROGRESS TOWARDS L-SAT REQUIREMENTS

The progressive build-up in the past 10 years of European expertise in the 12/14/20 GHz communications space technology, constituted a useful preparation for entering the L-SAT development phase.

The Canadian Communications Technology Satellite (CTS), launched in 1976, carried a 14 GHz parameteric amplifier and a 20 Watt 12 GHz Travelling Wave Tube Amplifier developed in Europe under ESA contract (Ref. 2). In 1978 the European Orbital Test Satellite (OTS-2) was launched. OTS-2 carries a 6 channel payload operating in the 14/12 GHz bands. A variety of communications experiments and services have been provided by OTS-2, that includes in particular frequency re-use by polarisation discrimination within the European coverage, TDMA testing, TV distribution and propagation experiments (Ref. 3).

In 1979, the main development activities were concentrated on low noise amplifiers and TWTA's at 20 GHz and, Electronic Power Conditioners (EPC) for 150W 12 GHz TWT in the frame of the Heavy Satellite (H-SAT) ESA programme.

PAYLOAD DESCRIPTION

L-SAT will carry a four element payload. The selection of the payload elements was based on the strength of market prediction of each mission type, payload technology benefits and the interest in demonstrating and promoting certain new services.

The Specialised Services Payload Element

This payload is designed to provide pilot specialised or business services to the whole European zone with small terminals equipped with 3 metre diameter antenna. This payload concept is intended to pre figure a future European system and to prove the key technologies which will be needed. The main features of the Specialised Services L-SAT Payload are summarised in Table 1.

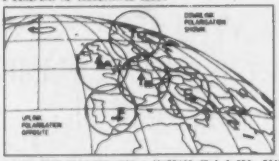
The payload configuration illustrated in Figure 1 comprises the following major elements :

- A receive-transmit 8 beam single offset antenna.
- FET wide band low noise amplifiers followed by mixers for converting the uplink channels to a common intermediate frequency of 825 MHz so that the SSTDMA RF switch matrix can interchange TDMA bursts between different repeater chains. Two different sets of local oscillator frequencies are used as to provide reception in either the 14 GHz or the 13 GHz bands.
- A four by four RF switch matrix :

The RF design of the switching matrix operating at 825 MHz is based on the use of four single port four throw (SP4T) switches associated with a conventional stripline circuitry.

- 30 Watt 12.5 GHz TWT amplifiers.

TABLE 1 : SPECIALISED SERVICES PAYLOAD CHARACTERISTICS

COVERAGE	o EUROPEAN AS ILLUSTRATED BELOW  o EACH SPOT BEAM PROVIDES A COVERAGE OF 1.3 DEG. DIAMETER o THE 5-SPOT PATTERN IS REPOINTABLE TO ANY OTHER VISIBLE PART OF EARTH
FREQUENCY	o UPLINK 13 OR 14 GHz o DOWNLINK 12.5 GHz
POLARISATION	o LINEAR
CHANNELS	o UP TO FOUR 18 MHz CHANNELS BY FREQUENCY RE-USE IN SPOTS A-C AND D-E o ONE 36 MHz CHANNEL SELECTED BY COMMAND
REPEATER	o FOUR 13/14 GHz RECEIVE CHAINS o FOUR 12.5 GHz TRANSMIT CHAINS
INTER-CONNECTIVITY	o AN SSTDMA SWITCHING MATRIX INTERCONNECTS ANY RECEIVE CHAIN TO ANY TRANSMIT CHAIN OR COMBINATION OF TRANSMIT CHAINS
G/T	o +1 DB/DEGREE K AT EDGE OF COVERAGE
EIRP	o +44.3 dBW AT EDGE OF COVERAGE
CO-CHANNEL INTERFERENCE SPOTS A AND C	o UPLINK C/I : 33 dB o DOWNLINK C/I : 33 dB
PAYLOAD USAGE	o DEMONSTRATION OF FREQUENCY REUSE BY SPOTBEAM SEPARATION o DEMONSTRATION OF ON BOARD SATELLITE - SWITCHED TIME-DIVISION MULTIPLE ACCESS (SSTDMA) o TELEVISION DISTRIBUTION OVER A SPOTBEAM o DEMONSTRATION OF MULTIPOINT VIDEO TELECONFERENCE OVER ONE SPOT BEAM

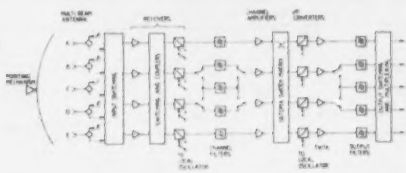


Figure 1 : Specialised Services Payload

The Television Broadcast Payload Element

The key features of the TV Broadcast payload are summarised in Table 2.

TABLE 2 : TV BROADCAST PAYLOAD CHARACTERISTICS

COVERAGE	o UPLINK	: EUROPEAN COVERAGE 3.3 x 2 DEGREE
	o DOWNLINK	: . BEAM 1 = 1 x 2.4 DEGREE HALF POWER BEAM WIDTH WITH A STABILITY BETTER THAN ± 0.1 DEGREE . BEAM 2 = 1.5 DEGREE HALF POWER BEAM WIDTH WITH A STABILITY BETTER THAN ± 0.2 DEGREE BOTH BEAMS ARE STEERABLE WITHIN EUROPE
FREQUENCY BAND	o UPLINK = 18 GHz o DOWNLINK = 12 GHz	
POLARISATION	o CIRCULAR	
CHANNELS	o TWO 27 MHz CHANNELS : . WARC CHANNEL 24 IN BEAM 1 . WARC CHANNEL 28 OR 20 IN BEAM 2	
G/T	o 0 dB/°K	
EIRP	o 62.4 dBW PEAK IN BEAM 1 o 62.7 dBW PEAK IN BEAM 2	
PAYLOAD USAGE	o PRE OPERATIONAL TV DIRECT-TO-HOME BROADCASTING SERVICE IN BEAM 1 OVER THE ITALIAN TERRITORY o EXPERIMENTAL TV DIRECT-TO-HOME BROADCASTING IN BEAM 2, AVAILABLE TO MEMBERS OF THE EUROPEAN BROADCASTING UNION (EBU) ON A TIME SHARING BASIS o TRANSMISSION OF A SINGLE, MULTILINGUAL, "EUROPEAN" PROGRAMME OVER THE WHOLE OF EUROPE FOR RECEPTION IN BEAM 2 BY COMMUNITY/CABLE INSTALLATIONS	

The payload configuration illustrated in Figure 2, comprises the following major elements :

- One receive 18 GHz single offset antenna,
- One transmit dual offset antenna designed to meet the 1977 World Administrative Radio Conference (WARC) requirement for the Italian territory service,
- One transmit single offset antenna,
- A two channel single conversion 18/12 GHz repeater which includes
  - . A redundant all-FET 18/12 GHz receiver,
  - . Three 12 GHz channel filters, 27 MHz wide,
  - . Four all-FET 12 GHz channel amplifiers with automatic level control via dual gate FET devices,
  - . Four high power, 230 watt RF, TWT amplifiers,
  - . Three high power waveguide switches and 2 output filters.
- A fine pointing system for beam 1 which includes :-
  - . A waveguide mode extractor - integrated in the transmit feed antenna for beam 1 - which operates at an uplink beacon frequency of 17 GHz and provides four RF outputs Σ_x, Σ_y, Δ_x and Δ_y. The amplitude of the two normalised signals are proportional to the angular separation, in the X and Y planes, between the direction of the ground beacon and the electrical boresight of the satellite antenna.
  - . A tracking receiver providing DC outputs proportional to the error functions : $e_x = \Delta_x / \Sigma_x$ and $e_y = \Delta_y / \Sigma_y$
  - . An antenna pointing mechanism with two stepper motors that controls the main reflector rotation in its principle planes.

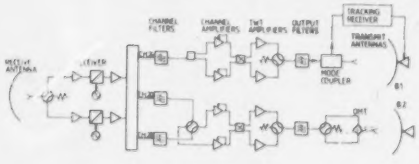


Figure 2 : Television Broadcast Payload Diagram

The 20/30 GHz Communications Payload Element

The main features of the 20/30 GHz Communications Payload are summarised in Table 3.

TABLE 3 : 20/30 GHZ COMMUNICATIONS PAYLOAD CHARACTERISTICS

COVERAGE	o TWO 0.6 DEGREE CIRCULAR COVERAGE AREAS, BEING STEERABLE WITHIN EUROPE
FREQUENCY BAND	o UPLINK 30 GHz o DOWNLINK 20 GHz
POLARISATION	o LINEAR
CHANNELS	o TWO 40 MHz CHANNELS
G/T	o +8 dB/°K AT EDGE OF COVERAGE
EIRP	o +52 dBW AT EDGE OF COVERAGE
PAYLOAD USAGE	o VIDEO TELECONFERENCE USING DIGITAL TRANSMISSION AT 0.44 MBIT/S o TELE-EDUCATION WITHIN A SPOT USING SIMPLE EARTH STATIONS DUAL DIGITAL OR FM MODULATION o DATA AND VIDEO TRANSMISSION

The payload configuration illustrated in Figure 3 is a conventional concept involving two identical transmit/receive single offset antenna associated with a two channel double conversion repeater with a 4 GHz intermediate frequency.

The low noise amplifier at 30 GHz is a parametric amplifier, which is a traditional technology for European industry. Paramp's have been flown on CTS, OTS and ANIK B and are still being manufactured for a variety of operational satellites at 14 GHz such as the European Communication satellites (ECS), the French Telecom 1, and the American G-STAR.

The choice of TWTA output power of 30W was made with the view of a potential application in the Italian ITALSAT programme.

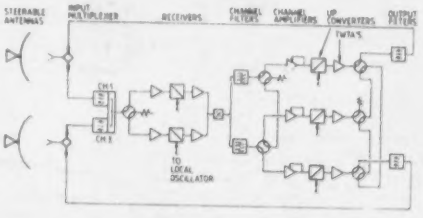


Figure 3 : 20/30 GHz Communications Payload Diagram

The Propagation Package Payload Element :

The major characteristics of the Propagation Package Payload are summarised in Table 4.

TABLE 4 : PROPAGATION PACKAGE PAYLOAD CHARACTERISTICS

COVERAGE	o EUROPEAN AT 20 AND 30 GHz o GLOBAL AT 12 GHz
FREQUENCY/ POLARISATION	o 20 GHz/LINEAR, SWITCHABLE BETWEEN ORTHOGONAL DIRECTIONS o 30 GHz/LINEAR o 12 GHz/LINEAR
EIRP	o 24 dBW AT 20 AND 30 GHz o 10 dBW AT 12 GHz
PAYLOAD USAGE	o PROPAGATION STATISTICS o ELABORATION OF WEATHER MODELS o TRACKING BEACON FUNCTION (12 GHz) FOR ALL L-SAT SYSTEM GROUND STATIONS

The payload configuration illustrated in Figure 4 comprises a coherent solid state frequency source at 12/20/30 GHz, a redundant TWT amplifier at 20 and 30 GHz, output filters and three horns.

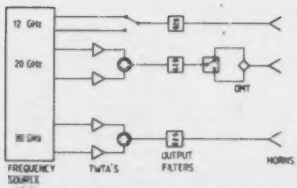


Figure 4 : Propagation Package Payload Diagram

Overall View Of the L-SAT Communications Payloads

The four payload elements are designed to satisfy the inter-payload compatibility requirements. Stringent filtering is implemented at the output of the eleven L-SAT transmitters to clean the RF spectrum in four receive frequency bands at 13, 14, 18 and 30 GHz. Similarly the design of the input filter of the L-SAT receivers are designed to provide attenuation at the high signal levels present at the L-SAT transmit frequencies in the 12, 20 and 30 GHz bands.

The payload mass adds up to 225 Kg. The total power required by the payload amounts to 2.2 KW. The majority of repeater hardware is mounted on the North and South panels (2.1 by 2.5 meters each). A general view of the spacecraft is shown in Figure 5.

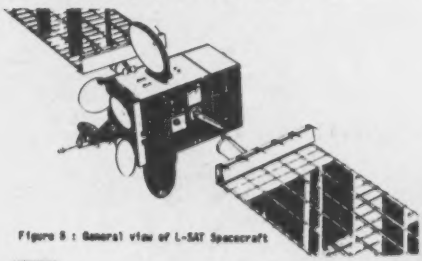


Figure 5 : General view of L-SAT Spacecraft

ANTENNAS

The L-SAT payload antenna layout is shown in Figure 6. The antennas are, with the exception of the Propagation Horns and the telecommand/telemetry antenna, configured as non-integrated reflector-feed assemblies.

Antenna pointing mechanisms (APM's) are employed in five positions for beam steering purposes by reflector rotation. In the case of the TV Broadcast Beam 1 antenna (TVB1), the APM may also form part of an RF sensing loop when beam pointing error signals are derived from the TVB1 feed chain and processed by a single channel tracking receiver. Each of the APM's are of an identical design based on a swash plate principle that realises a reflector interface rotation of up to 0.6 degree half cone angle (HCA) and featuring a return-to-zero facility in the event of single axis mechanical failure.

Conventional single offset configuration antennas are, with the exception of TVB1, employed. The TV Broadcast Beam 2 (TVB2) and Specialised Services Multibeam (MBA), reflector/APM assemblies are deployed from the spacecraft West and East faces respectively by similar antenna deployment mechanisms (ADM's) that incorporate deploy rate control.

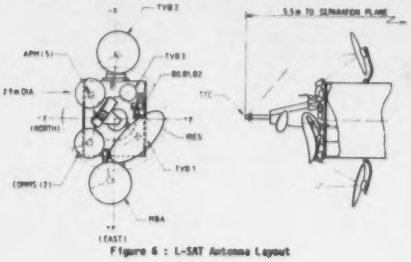


Figure 6 : L-SAT Antenna Layout

The TVB1 antenna is designed to meet the WARC 77 downlink (DL) radiation template, viz sidelobes, crosspolar, beamwidth and beam pointing stability, and employs a gregorian reflector concept that realises an elliptical beam cross-section from a circular symmetric feed illumination function. The resulting "astigmatic" reflector system has shaped reflecting surfaces but remains a focussed system.

The TVB1 feed chain is intended to operate at the DL and UL (uplink) RF beacon frequencies and employs a dual depth slotted corrugated horn with profiled cross-section to reduce feed length. RF sensing signals, Σx Σy Δx and Δy, are made extracted immediately behind the horn throat, the Σx and Σy signals being purposefully separated to reduce the pointing error that results from atmospheric depolarisation of the beacon signal. The particular mode extraction concept employed followed from the requirement to track a ground based beacon placed anywhere within the antenna half power beamwidth.

The complete feed chain circuit is shown in Figure 7 and the electrical engineering model (EM) in Figure 8.

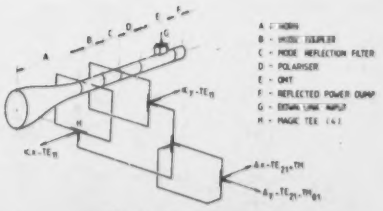


Figure 7 : TVB1 Feed Chain Circuit

Figure 8 : TVB1 Feed Engineering Model

Antenna pointing stability requirements are generally 0.2 degree (HCA) including spacecraft contributions with 0.1 degree (HCA) being placed on TVB1 antenna whilst RF sensing is operating. To assist in meeting these requirements, carbon fibre reinforced plastic (CFRP) is used extensively for reflectors, support tower and ADM structure for improved dimensions stability.

A general summary of the antenna equipment design and performance is provided in Table 5. Hardware status is such that all primary radiators have been breadboarded, the MBA feed/reflector assembly measured and a fully representative electrical model TVB1 feed chain completed. Specifications placed on the latter are particularly demanding and typical performances, measured within 20 deg of the feed boresight, at the feed chain interfaces, indicate cross polarisation levels of > 36 dB (DL), interport isolations of > 35 dB and difference channel null depths and peak unbalance of > 38 dB and < 0.2 dB respectively.

TABLE 5 : ANTENNA EQUIPMENT DESIGN AND PERFORMANCE SUMMARY

PAYLOAD ELEMENT	TX BROADCAST			20/30 GHz COMMS		SPECIALISED SERVICES			PROPAGATION		
ANTENNA DESIGNATION	TMB1		TMB2	TMB3	COMMS	MBA			BB	BI	BZ
TRANSMIT(T) OR RECEIVE(R)	DL	NL (BEACON)	DL	VL	DL	VL	DL	VL(a)	VL(b)	DL	DL	DL
FREQUENCY (GHz)	12.1 to 12.5	17.3	12.0 to 12.5	17.4 to 18.2	18.6 to 19.5	27.5 to 28.7	12.5 to 12.8	13.0 to 13.3	14.1 to 14.3	12.5	19.7	29.6
POLARISATION	LHCP	RHCP	LHCP or RHCP	RHCP	LIN (Y)	LIN (X)	LIN (Y) or Y) DEPENDING ON BEAM			LIN (Y)	LIN (X or Y)	LIN (Y)
NOMINAL HALF POWER BEAM-WIDTH (DEG) *	1D x 2.1B	0.9B x 2.2B	3.5 x 1.7	2.6 x 1.7	1.2	1.0	1.2	1.1	1.1	17.5	9	9
PEAK GAIN* (+ dBi)	45 †	28.7 (2) 33.8 (3)	41.2	31.5	42.1	41.5	39	40	40.4	28.3	25.4	25.5
SIDELOBE * (- dB)	14dC	-	25	25	-	-	14dB OVER 70%	OFF BEAM A FEW BEAM † AND BITA VERSA		-	-	-
CROSS POLARISATION (-dB) *	14dC	-	25	30	-	-	32dB OVER 90%			-33	-32	-33
MASS (KG) (INC MECHANISMS)	37.6		19.29	2.4	2 X 7.65		15.5			3.76		
NOMINAL APERTURE (M)	2 x 1 (ELLIPTICAL)		1.2 DIA.	0.675 DIA.	0.825 DIAMETER		1.2 DIAMETER			700MM (INTERNAL DIAMETER	96 MM DIA.	56 MM DIA.
CONFIGURATION SUMMARY	GREGORIAN "ASTIGMATIC" REFLECTOR SYSTEM WITH DUAL DEPTH SLOT CORRUGAT-ED AND PROFIL-ED FEED HORN		SINGLE OFFSET REFLECTOR SYSTEM WITH CORRUGATED FEED HORN		SINGLE OFFSET RE-FLECTOR SYSTEM WITH CROSS-POL OPTIMIZED HEXAGONAL APERTURE FEED HORNS, ONE PER BEAM					CORRUGA-TED CONICAL HORNS	SMOOTH WALL CONICAL HORNS	

(*) EXCLUDING ANY BEAM STEERING

RECEIVERS

The requirement placed on the three L-SAT receivers at 13/14 GHz, 18 GHz, 30 GHz are summarised in Table 6.

TABLE 6 : RECEIVER REQUIREMENTS

INPUT FREQUENCY RANGE (GHz)	13.175 to 14.1 WITH SWITCHABLE LO.	17.6 to 18.1	27 to 28.7
OUTPUT FREQUENCY (GHz)	0.8	12	4
NOISE FIGURE (dB)	4.3	5.8	4.5
TOTAL GAIN (dB)	27	55	57
GAIN STABILITY OVER TEMPERATURE (dB PEAK TO PEAK)	0.9	2	2
AMPTITUDE VARIATION : (OVER TEMPERATURE AND FREQUENCY)	0.2 dBpp † 21 MHz	1 dBpp OVER 500 MHz	2 dBpp OVER 700 MHz
INTERCEPT POINT REFERENCED TO RECEIVER OUTPUT (dBm)	+22	+ 25	+ 15
DC POWER CONSUMPTION (W)	6	2.9	4.5
MASS (Kg)	1.8 EXCL. LOCAL OSCILLATOR	2.2 INCL. LOCAL OSCILLATOR	1.5 EXCL. LOCAL OSCILLATOR
TEMPERATURE RANGE	-25°C to +60°C	-15°C to +30°C	-15°C to +50°C

14 GHz Receiver

The low noise amplifier consists of a single ended FET front end followed by three balanced FET pairs (NEC 137). The predicted noise figure of the low noise amplifier is 2.6 dB with a net gain of 27 dB.
The 14 GHz to 825 MHz down converter is a single balanced mixer fabricated on an alumina substrate. The two stage post amplifier provides a gain of 40 dB. The assembly of the breadboard model is being completed.

18 GHz Receiver

The 18 GHz front end design contains basically FET amplifier stages for the pre- and post amplifications. The 18 GHz input signal is amplified by a four stage low noise FET amplifier (4.5 dB at 25°C), then downconverted by a single balanced mixer to an IF frequency of 12 GHz, and further amplified by a first stage FET amplifier to an output level which is limited by the tolerable intermodulation requirement (C/I third order better than 45 dB). The local oscillator is derived from a voltage controlled oscillator which is phase locked to a crystal source of 78 MHz. Special design effort was assigned to the front end amplifier to obtain the lowest possible noise figure with currently available FET devices. The input of this amplifier contains a waveguide isolator with an insertion loss of 0.15 dB. The amplifier module is build up by four 0.5µA FET devices (NEC 137) mounted by thin film technique onto alumina substrate. Micro-strip isolators mounted into the same housing provide the required interstage decoupling of the two amplifier cells and good output match. Suitable bias and compensating circuits stabilize the DC operating point and gain of the amplifier versus temperature.
The following performance characteristics were obtained on the 18 GHz low noise amplifier breadboard model :

Gain	22	dB
Bandwidth	700	MHz
Noise Figure	4.5	dB (at 25°C)

30 GHz Receiver

A simplified electrical diagram of the 30 GHz front-end configuration is shown in Figure 9. Two designs were considered for the low noise amplifier at 30 GHz : a FET amplifier and a parametric amplifier. The reasons which led the L-SAT contractor to prefer the parametric amplifier solution were the uncertainty to achieve qualification of a 0.3 µA FET device within the L-SAT schedule constraint, the encouraging results obtained in early breadboarding of the parametric amplifier, and the experience gained in previous programmes in designing paramps at 14 and 20 GHz. The low noise amplifier is followed by a single balanced mixer for down conversion to 4 GHz. The post amplification is achieved by a five stage FET amplifier, the gain of which is determined by the linearity requirements imposed on the 30 GHz receiver.

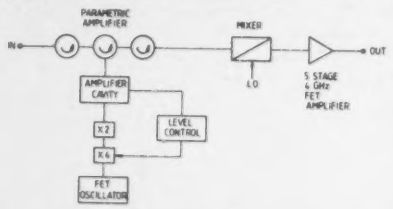


Figure 9 : 30 GHz Receiver Diagram

The heart of the receiver in terms of state of the art technology is represented by the parametric amplifier at 30 GHz. The design is essentially a tradeoff between achievable noise figure, mass and DC power consumption. The selected pump frequency of 88 GHz is generated by a cavity stabilized FET oscillator at 11 GHz of 250 mW output power followed by a times-four and a times-two varactor multiplier with a conversion loss of less than 10 dB. The amplifier cavity of coaxial type contains a varactor diode of 0.1 pF capacitance. Suitable coupling to a five port waveguide circulator with an insertion loss slightly above 0.4 dB, generates a double tuned amplitude response in excess of 750 MHz with 13 dB of gain. The microwave package, with the exception of the coaxial amplifier cavity, is realized in waveguide design which ensures a rugged mechanical structure. A breadboard model of the 30 GHz parametric amplifier is shown in Figure 10. Since the gain behaviour of the parametric amplifier is primarily dependent upon the RF pump power level (≈ 1 dB/0.1 dB of pump power change), a circuit sensing the forward current (0.1 µA - 20 µA) of the varactor amplifier is coupled back via an AGC circuit to the times four multiplier, the conversion loss of which is changed to stabilise the RF pump power level. To a certain extent it is still open as to the kind of technology to be used for the amplifier diode - diffused mesa or shottky device. Initial test results indicate that schottky type varactor diodes are superior in noise figure achievement (3.2 compared with 3.8 dB) and consume 3 dB less pump power at 88 GHz which is highly desira-ble to save DC power and to obtain suitable derating of the first mult-iplier stage.

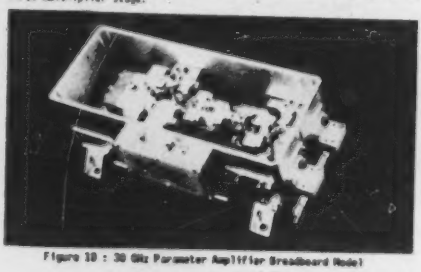


Figure 10 : 30 GHz Parameter Amplifier Breadboard Model

A long life test of 30 diodes of each technology mounted in suitable transmission cavities (at idler frequency) and exposed to three different temperatures will finally dictate the choice of the technology to be used for the amplifier diode. This type of test determines, by an indirect method, the long term stability of the diode parameters such as capacitance, I-V characteristics, series resistance and permits derivation of achievable stabilities for gain, gain slope and noise temperature, by analytical methods.

TRAVELLING WAVE TUBE AMPLIFIERS

Five types of TWTA's are required for the L-SAT payload. The key characteristics of the TWT, EPC, and overall amplifier are presented in Table 7.

TABLE 7 : TWTA CHARACTERISTICS

CHARACTERISTICS	COMMUNICATIONS TWTA's			BEACON TWTA's	
TWT					
• FREQUENCY BAND (GHz)	12	12	20	20	30
• SATURATION POWER AT END OF LIFE (W)	30	225	30	10	5
• CATHODE LOADING (A/CM²)	0.7	0.75	0.7	0.95 - 0.96	
• CATHODE TYPE	IMPREGNATED (B TYPE)	IMPREGNATED (B TYPE)	IMPREGNATED (B TYPE)	IMPREGNATED, OSMIUM COATED (M TYPE).	
• CATHODE LIFE TEST BACKGROUND	3 M HOURS ACCUMULATED BY 50 TWT's (TOS).		1 M HOURS ON 30 LIFE TUBES (TOS).	DIODE LIFE TEST.	
• GAIN AT SATURATION (DB)	55	50	50	35	33
• AM/PM CONVERSION (DEG/DB)	4.5	4.5	5.5	NOT APPLICABLE	
• COLLECTOR, NUMBER OF STAGES	2	4 + RADIATION COOLED	3	2	1
• EFFICIENCY (PER CENT)	40%	50%	37%	33%	28%
• MASS (GRAMS)	750	3000	1000	650	650
EPS					
• HELIX VOLTAGE (V)	4000	7300	4200	4100	6200
• TECHNOLOGY	PRESSURISED UNIT. HEXFET CONVERTER	PRESSURISED HIGH VOLTAGE UNIT.	POTTED HIGH VOLTAGE BLOCK HEATED BOX	POTTED HIGH VOLTAGE COMPONENTS/HEATED BOX	
• MASS (GRAMS)	2300	7200	2450	2550	2700
TWTA					
• POWER CONSUMPTION WORST CASE (W MAX.)	90	400	210	42	33

* MADE OF GRAPHITE

All L-SAT TWTA's are designed for a 10 year life and very low output degradation (≤0.2 dB) by means of regulating the cathode current of the tube. A helix delay line is used in all tubes, a brazed helix technology is only used for the 230W version. All amplifiers are supplied by a regulated 50 volts bus.

The development status is as follows :-

12 GHz/30W :

The breadboard phase has been completed successfully.

12 GHz/230W :

An elegant breadboard model TWT, shown in Figure 11, underwent an extensive thermal vacuum test. Test results are being analysed.

The manufacturing of the engineering model EPC is completed. This model, shown in Figure 12, is now being submitted to a full scale qualification programme.

The definition of the high voltage technology is complete. Samples underwent a qualification test programme based on Military standard specification. Now an extensive six months thermal cycling, in operating condition, of HV transformers is being started. The objective of this programme is to define what are the safe temperature limits of the technology proposed. If margins are not found to be sufficient, the satellite thermal control may need modifying to offer a less severe thermal environment.

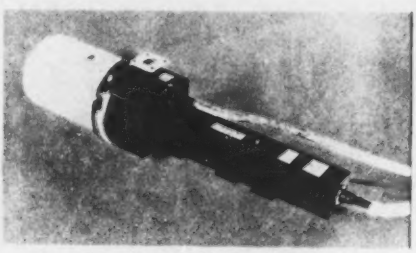


Figure 11 : 230W TWT Breadboard Model

20 GHz/30W :

Four elegant breadboard tubes were already available at the 25W power level. Five further tubes have been manufactured in 1982 with a variety of helix tapers.

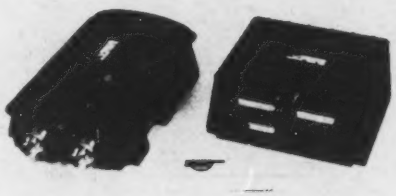


Figure 12 : EPC Engineering Model For 230W TWT

A compatibility test of the breadboard EPC with tubes has been completed.

A set of four high voltage transformers are completing a thermal cycling test to validate the power handling capability increase (compared to the design used on SIRIO 1 satellite) and to verify the design margins when transformers are operated over the L-SAT wide temperature range of -35°C to +70°C.

Beacons TWTA's (20, 30 GHz)

So far six 20 GHz TWT's, two 30 GHz tubes and one breadboard EPC, have been manufactured and tested.

CONCLUSION

The development of the L-SAT payload is now well underway and progressing to date satisfactorily.

The L-SAT payload design has been largely oriented towards the use of FET devices at 4, 12 and 18 GHz. Considerable effort is being applied to qualify technologies over a wider temperature range compared to previous ESA programmes. For the TWTA's, two conflicting approaches in technology content have been put in balance : new technology features (osmium coated cathodes, graphite collectors, hex FET's converters) on the one hand, and, the re-use of already flight proven technologies (B type cathodes, pressurized high voltage circuits) on the other.

Overall it is felt that in its present configuration the L-SAT payload will provide a useful in-flight demonstration of technologies that will be needed for future communication systems, and at the same time will stimulate development of small terminals at Ku and Ka bands.

ACKNOWLEDGEMENTS

A number of colleagues have contributed to this paper including Messrs. Forattini, Madden and Smidt. Their assistance is gratefully acknowledged.

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MAILING ADDRESS

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Mr. VOLKMER. On the space station, I assume that there has been—have been discussions between the ESA representatives and NASA.

Mr. PRYKE. We have been discussing informally with NASA ever since the establishment of the space station task force on ideas as far as cooperation is concerned. We have performed studies in Europe and have exchanged data with NASA in this area.

Mr. VOLKMER. But have you yet even determined within your own community exactly what type of proposal——

Mr. PRYKE. No. We——

Mr. VOLKMER [continuing]. Or policy that——

Mr. PRYKE. We have talked with NASA as the European Space Agency's executive. Any policy as regards collaboration with the United States on the space station program will have to be taken by our member states. In fact, the European Space Agency Council is meeting today and tomorrow, and one of the items on its agenda is the potential space station collaboration.

Mr. VOLKMER. In looking over your testimony, I quite agree that you should have the visibility that you desire and the access to the entire space station system if you do cooperate, and I think it needs to be a clearly defined area where you would be involved with the space station. Personally, I think this committee—the subcommittee and I think the full committee—would welcome the cooperation with ESA in developing a space station.

Mr. PRYKE. Those are certainly good words to hear, and I will transmit them back to my director general.

Mr. VOLKMER. The spacelab itself shows that I think it can be a very worthwhile endeavor. One thing that has just been handed me—and I don't know if you know it or not—and I have not been able to read the whole thing, but the headline says:

> Mitterand Outlines Military Space Station.
> French President Mitterand's proposed a European cooperation in space-based military recognizance observation programs which eventually could lead to European development of a manned military space station.

Mr. PRYKE. All I can say to that, Mr. Chairman, is that that announcement took the European Space Agency by surprise, and, to the best of my knowledge, it took the French Space Agency and the French Department of Defense by surprise. It was some sort of cabinet-level initiative.

Mr. VOLKMER. I see. It wasn't one of those that came up. It was one of those that came down.

Mr. PRYKE. That's right.

Mr. VOLKMER. And I understand by reading this—I read here that France also initiated design work on its own military observation satellite called SAMRO:

> But the activity was scaled down in 1982 due to defense spending constraints. The program is expected to be revived in the next few years when financing conditions are more favorable.

A comment—I guess an editorial comment—would be that if they're having trouble with just a military observation satellite with financing, I don't see how they're going to finance——

Mr. PRYKE. Well, of course, SAMRO would be a national program whereas——

Mr. VOLKMER. Yes, I understand.

Mr. PRYKE [continuing]. President Mitterand's proposal was at a European level.

Mr. VOLKMER. Yes, but there's still considerable cost.

Mr. PRYKE. That's right.

Mr. VOLKMER. Oh, yes. What lessons did we learn, if any, in the development of spacelab program between ESA and NASA that could be utilized if we have a joint effort on the space station between ESA and NASA?

Mr. PRYKE. I would say that the major lesson we learned was how to manage a very large international program, and if there is going to be close collaboration on the space station, we will be in the same situation again. When I say "manage an international program," I mean we in Europe learned how to manage it at the European level, and between Europe and the United States we learned how to run things on a trans-Atlantic level. And I think these lessons will be very important if we enter into some collaboration on the space station.

Mr. VOLKMER. Is there anything in the spacelab pricing policy that would affect the deliberations on the space station?

Mr. PRYKE. The space station pricing—sorry, the spacelab pricing policy is now a function of the overall pricing policy of the Space Transportation System. We have provided certain hardware to NASA free of charge as our contribution. NASA has also purchased certain hardware from Europe. That's now part of their inventory, and they will set the pricing policy as far as the utilization of spacelab is concerned on space shuttle missions. I think in any space station cooperation we are looking for a slightly different type of cooperation. This is why I said in my testimony we don't only want to develop hardware for the space station; we will want to be involved in the operational phase.

Mr. VOLKMER. All right. And when we talk about operation—I know this would be in the formative stages of policy decision, but are we talking about the presence of, say, astronauts within the space station as well as ground services in the operation?

Mr. PRYKE. I would expect so, yes, both crew and—orbiting crew and ground crew, yes.

Mr. VOLKMER. Is ESA contemplating or have there been any discussions with the Russians in regard to space station operations or——

Mr. PRYKE. No. We have—from time to time we have had discussions with the Russians on cooperation, mainly centered in the space science area, but apart from the French national initiative in which they flew a so-called spationaute in the COSMOS program, we have had no discussions at a European level.

Mr. VOLKMER. None as far as hardware for any type of program?

Mr. PRYKE. Not relating to the space station, no.

Mr. VOLKMER. We may have additional questions for the record which will be submitted to you in writing. We'll hold the record open until you can get the answers back.

Mr. PRYKE. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you very much for being here, and I'm sorry for the time that you had to wait, but, as I am sure everyone

in the room at the time found the testimony of our first witnesses——

Mr. PRYKE. I found it fascinating.

Mr. VOLKMER. It's very interesting. Our next witnesses we'll take as a panel, the Aerospace Safety Advisory Panel. Testifying will be Mr. Willis M. Hawkins, the chairman, retiring from it, and the new chairman, the incoming chairman, Mr. John Brizendine—how do you pronounce that?

Mr. BRIZENDINE. Brizendine, sir.

Mr. VOLKMER. Brizendine, all right. We'll start with Mr. Hawkins. Your statement, which we have been furnished a copy of, the joint statement here—you decide however you wish to present it, but it will be made a part of the record. You may either summarize or review it in total, however you so desire, and you all decide how you want to do it. I'll leave it up to you.

STATEMENT OF WILLIS M. HAWKINS, CHAIRMAN [RETIRING], AEROSPACE SAFETY ADVISORY PANEL, AND JOHN BRIZENDINE, CHAIRMAN [INCOMING], AEROSPACE SAFETY ADVISORY PANEL; ACCOMPANIED BY JOHN M. STEWART, NORMAN R. PARMET, SEYMOUR C. HIMMEL, AND HERBERT E. GRIER

Mr. HAWKINS. Mr. Chairman, what we propose to do is to summarize our statement, and of course attached to the statement is a copy of the entire——

Mr. VOLKMER. Yes.

Mr. HAWKINS [continuing]. 1983 annual report, which we delivered to the Administrator of NASA and his Deputy just last week. As you've noted, this is my last appearance because of the fact that we find a conflict of interest of the new contractor at Cape Kennedy, and so I regret having to leave this august organization, and I also extend, I think, the regrets of our friend from Grumman who was also on the committee and who has left. Grant Hedrick has been a real contributor to the Safety Advisory Panel. And you've also just been introduced to John Brizendine, who is going to take my place, and I have known John for many, many years, and I consider that this is a younger and substantially more capable chairman and he'll do very well. I would like to, before we get through, also recognize the contribution of Bob Rothi, who was a member of our Panel and who passed away, unfortunately, just recently, and he has made a major contribution to this particular report. And we all have appreciated his friendship and his contribution. We've had about four times a month, I think, factfinding sessions during the last year for members of our committee. We've visited all the centers from time to time, depending upon where the problems were. We've visited the contractors and headquarters. So I think we've covered the field pretty thoroughly. And I think that we can perhaps best summarize this by going over with you what we said last year, and emphasize to you in our conclusions and recommendations of this year's report which ones of those problems still exist.

Mr. VOLKMER. Before we do that, would you first identify the other members of the Panel that are there at the table?

Mr. HAWKINS. Oh, I'm sorry. John Stewart is a member of the Panel. You've already met John Brizendine. Norm Parmet, Sey

Himmel, and Herb Grier. Herb is at the end and was the previous chairman, prior to my ascension to the throne, if you will, and has been a major contributor for many years and will continue to contribute to the Panel. Excuse me. Excuse all of you folks. And I hope you folks will interrupt if you think that I have summarized too summarily and will intrude. Last year, as I looked over our report, we had a number of points that we made. In summary, we said that—we were asking the question whether the instrumentation was adequate to reach the performance envelope and be sure we were there. We questioned whether or not there was sufficient instrumentation to really prove the structural integrity of the bird. We suggested that the organization for operations in the shuttle could stand an awful lot of study and probably change; and we suggested also that sustaining engineering be incorporated into this new organization, if there were any; and that they should begin to address the problem of certification of hardware. We also pointed out that we ought to try the Autoland system, and I'll have a few more comments on that as I go along. We suggested that the main engine turbomachinery was in bad need of a lot of design attention, and that, similarly, the landing gear seemed to us to be too marginal. If we go through the 1983 conclusions and recommendations, as you'll see in our report, we have added really only one major emphasis, and that is the approach to the product quality and utility of the shuttle. This is a chapter that was mostly contributed by Herb Grier, and it was contributed on the basis of a request from NASA, who were a little worried—considerably worried—that each time they had a problem they seemed to change their quality assurance system to make the sieve even finer than it was before, but they weren't quite sure that they were getting at the problems. And I think that that is absolutely right, and that they probably have got to back off a little bit and include not only the people who are making these parts, the contractors, but also the engineers who are designing them, because a lot of the parts and pieces on the shuttle could stand some reassessment, as the R&D program has proceeded, as to whether or not they have been designed for competitive operation, rather than as an R&D article. You will find a discussion of this and some suggestions on how to approach it in our report. We think it's a major emphasis that NASA should enter into. We looked at the space shuttle's main engine program again in some detail, and we find that the response that NASA has made in this area is really quite good. They have now initiated and funded a program in which they're certificating the main engine all over again, in a sense, for a different rating. And they're aiming at a rating of 109 percent of their original rating, but they're deciding that while they're working at that they're going to restrain themselves to 104 percent of the main engine rating. And the reason for this—and we agree with it completely—is that the rotating machinery, the hydrogen and oxygen pumps, are very, very marginal. And if the aircraft or if the engine were operated at 109 percent, they'd probably have to be changed out on every flight. And that is not, of course, the kind of a thing you want for any kind of a repetitive flight operation. We have only one caution in this new program, which they have a 3 phase program really, the one in which to fix it today, fix it for tomorrow, and then redesign

it for the final engine. And we agree with all of it and are very happy that they have outlined that kind of program. Our caution is that in doing these testing programs that they approach it differently than they've done in the past. They have certificated the engine if it ran long enough at the rating they want to give them some margin in running time. We suggest this is the wrong way to approach a margin. What you really ought to do is to find out what it will stand and then derate the engine so that you know what your margin is, rather than estimating a running time. They have accepted this criticism, and they're looking at their program to see if they can't redesign their test program properly.

The main landing gear is an old friend. We've been talking about it for some time, and we believe that the landing gear itself has now brought the problem sufficiently to their attention that I think they're going to look at it. Just in the last few weeks they've had a major symposium down at Johnson to take a look at the brakes. We think they should look further at the landing gear, and this is defined in our outline, and I hope that they will. The logistics and maintenance problem, also an old friend from a suggestion of the Safety Advisory Panel—it's not that we feel that we're experts in management, but that we recognize that when you get to flying this thing in a repetitive way, if you haven't planned for it and haven't set it up to do it that way, the opportunities for making shortcuts when the schedule gets tight are too many. And if you haven't prepared for it, you may get into a safety hazard by taking such shortcuts. And so we suggest that they get at this, and particularly we suggest that they put down now some arbitrary maintenance on this shuttle, so that you can plan these schedules and know that you're going to have to maintain this thing on a repetitive basis and schedule it now instead of later. I think that this suggestion is being implemented in NASA, and this last year we have seen some very commendable improvements in making logistics and spares planning. They have an integrated logistics panel now working with the Air Force, and this seems to be working out quite well. We have suggested in our report, however, that having cochairmen for such a panel, generally speaking, doesn't work in the long run when you've got a hard decision to make, and that they ought to select one as chairman and make those decisions. The structural integrity problem still exists, and we believe that their plan for instrumentation in the future will probably get at this within the next few flights. They have scheduled how they're going to get the structural instrumentation, and the whole panel, I believe, will reassess those when they get the loads from the flights. It's obvious today that their estimate of what they've designed the shuttle for, the aerodynamic estimates, are not correct and that, therefore, they're going to have to redo their structural assessment of the shuttle and get the loads in the right places before you can reach out to the far corners of the shuttle envelope. This is now in process, and they have now contracted to do a reassessment of the shuttle loads. Probably the most serious of our suggestions has to do with pitch control in landing. The shuttle is an awkward beast to land at best. If it weren't for the training that's gone into these shuttle astronauts and their absolute capability, I think the exposure to a possible hazard in landing would have been

almost unacceptably high. The thing, when you pitch it to land, if you try to slow it down, the first thing it does is descend faster, and the lag in picking up lift to flare it for landing is very difficult to handle. And it is the problem that exists on trying an automatic landing. We had a knockdown, drag-out session down at Johnson with the astronauts and the designers on why they didn't try the autolanding, and we are convinced that they've got good reason for not trying it yet. And that is that if you waited until too late to pick it up manually, then the pilot will make more errors than even it could make in an erroneous configuration, and that the hazard would be too great. And we've looked at it in detail, and we believe that we agree with them. Therefore, we are not pressing that they try the autoland yet. Now one of the things we do suggest, however, is that they try to change the pitch control in landing and that they take—well, they ask Langley, who understands the airplane pretty well, to go ahead and study what could be done. And we've suggested that maybe adding canards to the thing for control might work. And they, I believe, are going to attempt that kind of an investigation. It would be a very difficult kind of change to make, but if it were the right thing to do, maybe we should do it. It seems to us that it might be possible to double the lift coefficient you could use on the shuttle for landing, which would reduce the speed in landing and reduce the hazard thereby, and probably expand the number of available airports that would be available for the safety of the shuttle, make the brakes much easier to handle, and probably make ditching in the open ocean feasible. Now this—well, in addition, of course, it would reduce the training cost because the thing would fly more like an airplane. And, therefore, it would save some dollars. In any case, I think they're going to look at that. The shuttle processing contract, of course, is a different and a partial perturbation in the direction of operations. And because of the fact that I'm going to have to retire for the same reasons, I'd like John Stewart to cover that in some detail.

Mr. STEWART. Thank you, Mr. Chairman. I know that the shuttle processing contract is an item of interest to this subcommittee, and because of its obvious safety implications, it's been of interest to the panel. And we have been monitoring it reasonably closely, and will continue to do so. So far, however, it's our feeling that things are proceeding quite well and that Lockheed did an excellent job in retrospect in responding to the RFP and the management structure which they put together appears at this juncture to be really quite responsive to the needs and the concerns that we would have in terms of the responsibilities a shuttle processing contractor would have to meet. And responsibility was clearly fixed in their organizational scheme; the tasks were apportioned sensibly; and they appeared ready to go to work. As of early December—and we are in the process of checking further, right this week, as a matter of fact—but as of early December, the so-called capture rate of employees of the incumbent contractors was quite satisfactory, which means that the skilled personnel who are needed to do the job were going to work for Lockheed, and this was very encouraging. As we said last year and as we say again this year, the one firm recommendation that we have made and make again this year is that we would urge NASA to move as expeditiously as possible into at least

outlining the longer term institutional structure that will be in place to manage an operational system; that the absence of this structure continues an area, I guess, of ambiguity, you might say, between the roles of the R&D centers at Marshall and Johnson, in particular, KSC and the shuttle processing contractor. The whole question of logistics is an example. At this point, even though obviously the whole logistics function is a very crucial one, that remains the responsibility of Johnson and Marshall and not the shuttle processing contractor. And there is a transitional period that at this point will run into 1986 before those—before that transition is complete. And so it's been our feeling all along that the extent to which NASA could come to some conclusions about what sort of operational entity is going to manage the shuttle for the long run, that would be a major—of major assistance to a successful shuttle processing contractor experience. There are more details in our report, but those are the principal conclusions that we reached in this area.

Mr. HAWKINS. Thank you, John. We haven't spent all of our time on the shuttle. We have spent quite a bit of time looking at the flight operations that NASA engages in for R&D purposes as well as administrative purposes, and find that there is a kind of a decentralized control of this. And we believe that the headquarters of NASA needs to revitalize its own interest in how flying is going on in all of their centers. And they have responded well. They revitalized the Intercenter Aircraft Operations Panel, and they're exchanging information now in a very clear way. The Aircraft Management Office has been added to headquarters and is beginning to function to produce headquarters policy in terms of how you fly and how you control the flight operations at the centers. That, too, is working well. They made a contract with ECOsystems International to take a look at their flight operations, and that study was good and it was pertinent, and the results of that study are now being incorporated into headquarters policies. So that response has been good. Now our complete report covers not only these conclusions and recommendations, but also covers what we have done in some detail in looking at the inertial upper stages, the Centaur, the EVA operations, the orbiting refueling experiments, the filament wound solid rocket cases, et cetera, and et cetera. The light external tank, the lightweight one, came under our perusal at the middle of the year, and NASA's response to that was excellent, and it turned out that that was just fine, that our concerns were unfounded. I think that if you're interested in any of those, you could certainly look, and I suspect that the things you're interested in will be—will come more in questions rather than us going in detail in all of these items. Now as far as the future programs are concerned, John Brizendine is going to have to do those, and I've asked him to get up to speed pretty rapidly and to tell you about that.

Mr. BRIZENDINE. Thank you, Willis. Mr. Chairman, this being my first appearance before this subcommittee, I would take a moment to thank Willis Hawkins for the excellent leadership he's provided this Panel. I know the other Panel members join me in expressing a great deal of gratitude to Willis. I also thank him for his good summary of the many facets of the Panel's work during the past year. I would see no reason to change the Panel's factfinding mode,

at least not significantly, and will continue as before. Where necessary, we will use specialists, the key expertise, wherever we deem it necessary to meet the Panel's obligations. In discussing the program objectives for the National Space Transportation System with NASA senior management, I find that they've placed safety assurance at the top of the list of considerations. These, of course, are followed closely by the other program objectives such as increasing reliability, the ontime and timely launch performance, cost-per-flight reduction, payload performance increases, increased user opportunities, and capacity utilization. I think those are the basic elements that we would see in any major program, be it the program such as the Space Transportation System or you'd find it in a commercial type of program. But in providing the safety assurance assessments, the Panel, as you can see by the material in our annual report, will examine many related program areas, both technical and managerial. I think the Panel appreciates, and I think the subcommittee will appreciate, that safety assurance must delve more broadly than, say, only the technical aspects. Managerial decisions can greatly affect safety. In 1974 [sic] we expect to continue a major part of our effort on the shuttle program, and we will be focusing on areas such as the processing contractor progress. I think that's still worthy of tracking carefully. We'll be looking at the maintenance and logistics plan. At the very beginning of such an operational system comes a maintenance plan. That's where you start. It will dictate the logistics. It will probably affect greatly the ability to turn around and launch to schedule. We'll be looking at payloads and the upper stage propulsion systems that will be utilized, as well as their interface with the ground flight—ground and flight aspects of the system. These will include the Centaur and the inertial upper stage and the PAM's. We'll be looking at specific payloads, such as the orbital refueling mission. We will be looking at the certification process for the hardware and the software involved in these missions. We'll be looking at things such as the tethered satellite system, demonstrating deployment of a tethered subsatellite as far as 100 kilometers from the orbiter, which should create some interesting safety considerations, when one considers the variety of possible system configurations and multibodied tethered dynamics, control systems, and the like. The development of improved components for the Space Transportation System, such as the filament wound case for the solid rocket motor and the orbiter main engine refinements will also be tracked closely. These things, of course, will affect greatly achievement of some of the objectives that I outlined earlier. Other matters of concern in 1983 report will be tracked and followed, with particular emphasis on design suitability, as Mr. Hawkins mentioned, product quality, and the certification policy for design improvements. I think the Panel will recognize that you can improve yourself into a different problem if the certification process isn't managed properly. Beyond the Space Transportation System, the shuttle will be beginning to review the space station from the viewpoint of understanding the technical and management approaches involved, assuring that safety and all of its ramifications will be a part of that program, and any panel comments and recommendations may be incorporated into the program plan in a timely and early manner. We'll also continue to

monitor NASA's policies, procedures, and management of safety assurance of both their administrative flying and the research and development flying. And, of course, we will respond to any special study ad hoc team requests that we may receive from NASA headquarters, NASA management, such as was done in the past year when Sey Himmel worked with the main engine and APU unit teams and Dick Battin worked with the Orbiter General Purpose Computer Committee. Well, these outline broadly and roughly some of our activities in the coming year. One has the hope that there aren't too many surprises and need for the Panel's getting into unknown areas, but I'll assure you that the Panel will pursue its obligations diligently, and we look forward to the pleasure of working with the subcommittee. I personally am honored to be a part of this organization and look forward to working with the subcommittee. Thank you very much, Mr. Chairman.

[The prepared statements of Mr. Hawkins and Mr. Brizendine follow:]

STATEMENT OF

WILLIS M. HAWKINS
Chairman (Retired), Aerospace Safety Advisory Panel

before the

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES

Mr. Chairman and Members of the Subcommittee:

This is my last appearance before your subcommittee as Chairman of the Aerospace Safety Advisory Panel. As I retire from the Panel, I welcome and introduce to you the new Panel Chairman, John C. Brizendine. Since John will be in charge for 1984 and beyond, I will discuss only our calendar year 1983 findings, conclusions and recommendations and he will discuss future Panel activities along with any comments he may have regarding our report to you. Other changes in Panel membership are noted in our Annual Report dated January 1984. This report forms a part of my statement and is attached.

The Panel held its annual meeting on February 15, 1984 at NASA Headquarters and presented its detailed report to the NASA Administrator and Deputy Administrator. As in previous years, Panel fact-finding sessions have been conducted on the average of four times each month. Members and consultants visited seven NASA facilities, as well as NASA Headquarters, and numerous NASA contractors. Although our attention has been primarily focused on the Space Transportation System, there have been a number of visits to assess aeronautical operations and attendant flight safety. All of our

efforts have been supported by the Panel Staff Director through in-depth and continuous participation in NASA activities.

The Panel's report to you last year covered eight primary concerns:

(a) The adequacy of instrumentation and flight plans to demonstrate the vehicle system performance envelope.

(b) The demonstration of structural integrity and a cautious approach to performance improvements.

(c) That STS operations, although different from an airline's, could benefit from airline logistics and maintenance procedures to minimize turnaround time without jeopardizing flight safety, and that a unique organization should be developed to achieve this.

(d) Sustaining engineering for STS operations might best be served by divorcing it from the normal R&D engineering functions at the NASA Centers.

(e) Policy and standards for hardware/software certification and the need for NASA policy and an independent certifying function.

(f) Autoland for the Orbiter.

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(g) Space Shuttle Main Engine turbomachinery limitations and the required redesign for life and high performance.

(h) The need to take a hard look at the current Orbiter landing gear subsystem.

For this hearing, I propose to summarize our current concerns, some of which are "carry-overs" from previous years. Included are Panel suggestions which might resolve these concerns.

1. Product Quality and Utility becomes more important now that the major task for NASA and its contractors is more one of replacing and fixing during turnaround, along with gradual system enhancements to reduce cost or improve performance of the Space Transportation System. Emphasis must be placed on assisting contractors and sub-contractors to produce the highest quality of product oriented toward operational suitability. A basic concern is that the design for most of the Shuttle components is at least ten years old. Industry has progressed and new developments and design concepts have produced better and more reliable products. This, coupled with difficulty in the reproduction of older units, suggests that design change may be essential to achieve maximum reliability. The problem that this concept aging process poses is that NASA cannot allow changes in design or substitutions in components without requalification of the hardware along with comprehensive consideration of the effects of the

change. It would seem to be in order to determine in advance the extent of obsolescence, cost versus reliability improvements, the "delta" qualification requirements for such updated equipment, and establish a priority plan for design modernization.

2. The current design of the Space Shuttle Main Engine, with the exception of the turbomachinery, appears to be suitable, assuming satisfactory completion of the specified acceptance tests. Suitable in this case means seven flights at full power level of 109% of the original rated power, called "100%". The turbopumps providing high pressure oxygen and hydrogen working at the 109% level are currently only suitable for one or two flights before removal for teardown and inspection. The Aerospace Safety Advisory Panel agrees with NASA's prudent decision to limit the operation of these engines to the 104% thrust level which reduces the engine internal loads permitting more flights with greater operating margin. The Main Engine project has embarked on a three-phase program to achieve a long-lived, reliable full-power level (109%) engine. The Panel supports this organized approach to achieve adequate reliability and performance of the engine. The Panel emphasizes the importance of setting objectives in terms of demonstrated margins of stresses, temperatures, loads, etc., rather than trying to achieve arbitrary running time at a given thrust level. Having demonstrated improved margins, it is important not to operate at the highest level tested, but to operate at performance levels where these prudent margins are not violated.

3. The Orbiter main landing gear continues to concern the Panel. We feel that a complete structural and mechanical suitability review should be made by an engineering team with commercial transport experience for the purpose of suggesting alternative landing gear configurations and setting target margins for structures and the wheels, brakes, and axles. It appears that there are some less extensive improvements that might be worthwhile:

(a) Move the tire centerline inward toward the shock strut about one inch and increase the tire size as much as the diametrical clearances will allow.

(b) With the larger tire and internal wheel space, redesign the brake for greater energy and torque capacity using structural carbon.

(c) Support the brake on the axle near the inboard bearing to minimize the impact of axle bending.

4. Logistics, maintenance, supply and support programs received much more NASA attention as the positive impact of such programs on reliable and safe mission operations for the total Space Transportation System was recognized. Considerable progress has been made in meeting current Space Transportation System logistic needs but the demands of 24 flights per year by 1988 requires further steps and investment. The Integrated Logistics Panel which provides the coordination not only between various NASA organizations but also between NASA and the

United States Air Force is alive and well. However, to meet the needs of the future it appears to the Panel that NASA and its contractors should face up to:

(a) Establishing a single authority that is responsible for all logistics so support the Space Transportation System.

(b) Establishing an overall maintenance plan to provide for operations in the next decade.

(c) Clearly establish the roles and responsibilities of the Shuttle Processing Contractor at KSC in the overall logistics scheme.

(d) Establish the necessary logistics plans to support major payloads and payload elements such as the Spacelab, Centaur and Inertial Upper Stages.

5. Orbital structural integrity at all points within the "flight envelope" still requires flight data and analyses beyond that currently available. The initial flights of the Space Shuttle were designed to be reasonably benign with trajectory and performance capabilities to be expanded with each flight. Only a bare minimum of valid flight data is available to validate predictions of structural loads to assure that the safe strength of the vehicle is not exceeded. This applies to all Orbiters, but it is more critical for Orbiters 103

and 104 whose structures were lightened in a weight reduction program. To operate the Orbiter up to its safe strength with confidence, aerodynamic loads in ascent and thermal loads in descent must be more thoroughly defined. To do this, the Panel recommends the derivation of a new set of loads based on the latest wind tunnel and flight data and further recommends that the final derived structural loads be validated with full-scale flight data. This will require sufficient sensors placed at critical locations on the fuselage and wings along with a recording system of large enough capacity and data rate to obtain firm confirmation of the assumed loads and their distribution.

6. Orbiter landing speed and pitch control concerns have been discussed by the Panel in prior reports. Excessive landing speeds and control sensitivity result in:

(a) A continuing potential for a landing accident.

(b) Limitations on choice of abort sites.

(c) Risk of destructive brake malfunctions.

(d) Non-survivable open sea ditchings.

(e) Lengthy and expensive training programs.

Program management recognizes these problems. The Panel has looked at "wing tiplets" and "canards" to alleviate some of the undesirable

control characteristics and recognizes the difficulties inherent in their incorporation. The Panel has followed the many, more simple approaches to the improvement of the flight controls during landing and none of these - software modifications, revised feed-back paths, etc. - appear to be powerful enough to overcome the inherent instability and the impact of control movement on lift coefficient. The lack of a landing incident to date is a tribute to the skills of the astronauts, and to the carefully planned and executed training program. Nevertheless, it is the Panel's view that major control and lift coefficient improvement will be required for future operational success.

7. The Shuttle Processing Contract, which consolidates under a single contractor all ground processing and launch and landing services, went into effect October 1983. The Lockheed team which includes Grumman Technical Services, Inc., Morton-Thiokol, Inc., and Pan American World Services, Inc. will make the full transition, assuming all responsibility at Kennedy Space Center, following the launch of STS mission 41-B (February 3, 1984) so that they will be fully responsible for the next launch STS-41-C in April 1984. The planning, preparation, and initial actions taken by both the SPC and NASA appear to be thorough and working well so far. The Panel believes that NASA can further help the Space Shuttle Contractor in carrying out its responsibilities through such actions as the establishment of a unified logistics system, the acquisition of an adequate number of spares, the definition of major and minor overhaul sequences, and the development of coordinated launch schedules for Kennedy Space Center and Vandenberg Air Force Base. The Shuttle Processing Contractor must be a full

partner in planning major hardware acquisitions and enhancements that relate to Shuttle processing. Lockheed has created an "external" Safety Advisory Board (modeled in many respects after the Aerospace Safety Advisory Panel) that will meet quarterly to examine the safety aspects of their operations.

8. Safety of flight operations associated with both administrative and research and development aircraft were closely followed during 1983. Of note are:

(a) The revitalization of the Intercenter Aircraft Operations Panel which has provided a needed forum for the exchange of both safety and flight operations information.

(b) The reorganization in NASA Headquarters that established the Aircraft Management Office as the single office for directives and policy leadership for aircraft operations. This should provide leadership and more consistent communications.

(c) The recommendations from ECOsystems International, Inc. constructively reinforced many of the previously reported findings of the NASA in-house review teams to shore up communications and provide policy direction for flight operations.

Panel members will follow the Headquarters-field relationships during 1984, and the field performance to see whether further augmentation of Headquarters "control" should be recommended.

The total report which we have delivered to NASA contains substantial detail on the logic which supports the Panel's conclusions and recommendations. An up-to-date list of Panel members, consultants and staff are listed in the report. Covered in the annual report are discussions of the Intertial Upper Stage propulsion units, Centaur propulsion systems, Extravehicular Activities (EVA) including space suits and the manned maneuvering unit, the Orbital Refueling Experiment, the Filament Wound Solid Rocket Case, and Lightweight External Tank. All of these received attention during the past year and, with the exception of the External Tank, the Panel will continue to monitor these elements as they are further developed. The Filament Wound Case and the Centaur/Shuttle represent advances in the state-of-the-art and have safety implications.

John Brizendine will now discuss the Panel's plans for 1984, after which I suggest that the members of the Panel, with your permission, offer any comments that will augment, clarify, or correct what I have presented. We are, of course, all available to discuss any areas of interest that you may wish to explore.

STATEMENT OF

JOHN C. BRIZENDINE
Chairman, Aerospace Safety Advisory Panel

before the

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Mr. Chairman and Members of the Subcommittee:

This is my first appearance before your subcommittee as the new Chairman of the Aerospace Safety Advisory Panel. I want to thank Willis Hawkins, the retiring Chairman, for his excellent past leadership of the Panel and for his summary covering the many facets of Panel activities this past year. As he noted, I will describe briefly the Panel's efforts for 1984. Attached to my statement is a brief resume of my own background, for the subcommittee's information. Since retirng from my last position as President, Douglas Aircraft Company, I have been doing consulting work with the broad aerospace industry.

The Panel's fact-finding mode will continue as before and, where necessary, I would expect to bring specialists into this fact-finding where needed to meet the Panel's obligations.

In discussing the program objectives for the National Space Transportation System with NASA senior management, I find they list "Safety Assurance" first followed closely by: increasing reliability, on-time launch performance, cost per flight reduction, payload performance increase, increased user opportunities, and maximum capacity utilization. This same basic

listing would most likely be applicable to all manned space and aircraft operations and is one which we heartily support. In providing its "Safety Assurance" assessment, the Panel, as you can see by the material in our annual report, examines many related program areas, both technical and managerial. Thus you will find a variety of expertise among the Panel members and consultants.

Panel activities in 1984 will continue to focus on a number of aspects of the Space Transportation System as it approaches full operational status. We will include at least the following areas:

1. Shuttle Processing Contractor progress at Kennedy Space Center including their working relationships with NASA Centers and associated contractors.

2. Space Transportation System Maintenance and Logistics plans and their implementation, including the NASA-Contractor-Air Force coordination for both ground and flight hardware and software.

3. Payloads and Upper Stage Propulsion Systems and their interfaces with the ground and flight Space Shuttle System. These will include the Centaur, Inertial Upper Stages, Payload Assist Modules and specific payloads such as:

a. The Orbital Refueling Demonstration showing on-orbit transfer of hydrazine propellant from a storage tank through a zero-G servicing system into a flight-type propulsion module. The Panel is interested in the certification process for the hardware and software, the safety analyses dealing with Extravehicular Activities in the Payload Bay and the handling of hydrazine.

b. The Tethered Satellite System demonstrating

deployment of a tethered subsatellite as far as 100 kilometers from the Orbiter. This system has potential for safety concerns when one considers the variety of possible system configurations, the complexity of multibody tethered dynamics, the deploy and control system, and the numerous operational constraints associated with deployment, stationkeeping, and retrieval.

4. Development and certification of Space Transportation System component improvements such as the Filament Wound Case for the Solid Rocket Motor and the Orbiter Main Engine Refinements.

5. Other STS matters of concern noted in the Panel's 1983 annual report, with particular emphasis on design suitability, product quality, and certification policy.

The Panel will begin a review of the Space Station, from the viewpoint of understanding the technical management approach to assuring that "safety" in all its ramifications are a part of the program and that any Panel comments or recommendations are provided early enough to be evaluated and where required...factored into the program in a practical manner.

We will also continue to monitor NASA's policy, procedures, and management of safety assurance for both administrative flying and research and development flying.

We will, as requested by NASA, support special study and ad hoc teams such as was done this past year where Sey Himmel worked with the Space Shuttle Main Engine and Orbiter Auxiliary Power Unit teams and Dick Battin worked with the Orbiter General Purpose Computer committee.

I appreciate this opportunity to have introduced myself and the near-term plans for the Aerospace Safety Advisory Panel. It will be my pleasure to work with you and your staff as well as with the NASA and contractor organizations to further assure safe and successful aerospace operations.

RESUME FOR

JOHN C. BRIZENDINE

John Brizendine was born in Independence, Missouri and attended public schools there followed by graduation from the University of Kansas with a Bachelor's and Master's Degree in Aeronautical Engineering. He furthered his education with attendance at the University of Southern California Graduate School of Business and later attending the Managerial Policy Institute. During World War II he was a naval aviator with ratings on single and multi-engined aircraft.

John completed 33 years with the Douglas Aircraft Company in May 1983 after trying his hand at teaching at the University of Kansas after college graduation. At the time of h's retirement, John was President of the Douglas Aircraft Compnay, Inc. now a part of the McDonnell Douglas Corporation and is located in Long Beach, California. His career included flight test work on a variety of high performance research and development, military and commercial aircraft. A partial list of these aircraft includes the C-124, SF4D-1, D558-II (the first aircraft to exceed a speed of twice the speed of sound), X-3, A3D, C-133, DC-8. He was program manager of the DC-8 and DC-9 and program director on the DC-10. John held a number of executive positions including Assistant to the Vice President, Aircraft Division, then to Vice President of Engineering, Executive Vice President then as President of the Douglas Aircraft Company in 1973 until his retirement.

He is a member of a number of technical and civic organizations and has received a number of awards including the Federal Aviation Agency's Award for Extraordinary Service," Distinguished Alumnus of the University of Kansas, elected a Fellow of the AIAA and Tau Beta Pi honorary engineering society.

Mr. VOLKMER. I just want to say that we appreciate your work and dedication to the efforts. And I note in the statement, Mr. Hawkins, a recommendation regarding the landing gear. What reaction have you had from NASA in regard to those recommendations?

Mr. HAWKINS. The reaction we've had from NASA up to now has been that the landing gear didn't need any fixing. Now, however——

Mr. VOLKMER. General Abrahamson gave us a little bit different viewpoint on that yesterday.

Mr. HAWKINS. Well, I said "up to now." I think——

Mr. VOLKMER. I don't know what they plan exactly to do.

Mr. HAWKINS. I think that the reaction of headquarters now and Jim Abramson is that something needs to be done, and Johnson has just had themselves a complete symposium on the design of the brakes. This has only taken place about 2 or 3 weeks ago, and they brought in folks who had experience in the commercial aircraft business. And it was our recommendation that they go a little beyond that, and I think they will, which is to put together a special review team of men who have had experience in the commercial design business, the wide body and the new narrow body airplanes, and take a look at the whole landing gear design, rather than just the brakes, because I think they are all hooked together and you can't fix one without getting it all fixed. The real problem—and it's an understandable problem—is that this landing gear is only used to land on, whereas in a normal aircraft the landing gear has to be designed for very heavy takeoff, refused takeoffs, and all sorts of other things. The result is that a normal aircraft landing gear has substantially more margin in its design for the landing condition only, and, therefore, it only reaches its design corner, if you will, once or twice in a lifetime of many, many, many thousands of hours, whereas the shuttle landing gear comes up to its design load almost every landing. So the margin doesn't exist in the gear, and this is unusual. It's understandable that they would have designed it that way, to save weight, and I think there's just not enough margin there, and they're going to have to go back because you can't design the thing quite that thoroughly. You can't assume what kind of load it's going to get thoroughly. I think they will go into another review. Incidentally, while you're thinking about it, I would like to say something I didn't, and that is that the whole Panel—it's remarkable the welcome that we have in NASA. Although we wrestle with them, they have never, ever, as near as we can tell—and I think we could—kept from us any kind of data that we've asked for. They've offered data that they thought would be helpful, and from headquarters right down to the guy on the bench NASA has stayed open for us to find out what we need to find out. I think your committee ought to be assured by that.

Mr. VOLKMER. Well, in order to facilitate it, I think I would like—I was just telling the staff what I want them to do, to prepare a letter why these recommendations—you know, what's wrong with the recommendations and what are the problems with the recommendations with regard to the landing gear, and see if I can get an answer. I can see, you know, the problem that you're going to

have to change the whole part for the wing and everything else because you're going to have a large-sized——

Mr. HAWKINS. Oh, it's—we're not suggesting all that. I think there are ways and means in which the landing gear can be fixed without destroying the whole shuttle.

Mr. VOLKMER. I don't mean destroy the shuttle. I mean maybe you have to have some modifications where the wing—you know, it fits up into the wing and everything.

Mr. HAWKINS. Well, I—this is the area in which Bob Rothi worked the most before he passed away, and he made a number of suggestions—he's been in the business for all of his life—that wouldn't have been very difficult to incorporate. Of course, change is always difficult to incorporate and certify, but I think there are ways and means of fixing this landing gear so it will go away from our annual reports.

Mr. VOLKMER. That's—you use the word certify. I'd like to ask you or anybody on the Panel to suggest—do you have an opinion as to whether or not NASA has an adequate review procedure for deciding when engineering and process changes on the shuttle can be flown without first testing the changes on the ground?

Mr. HAWKINS. Well, I think that's making it a little too specific, the question that is. But what we note in NASA's whole operation is that each center, you see, certifies its own design, and we find inconsistencies in the certification, as to how they approach it, depending upon which center is handling the problem. And, furthermore, certification changes depending upon the pressure as to when you need this thing and whatever the change happens to be. And we have suggested to NASA that they take a headquarters policy look at how you certify things, to try to issue policies that will make the certification more consistent, and in our case I think maybe even faster, than they now do it. They have tasked the Chief Engineer at NASA to take a look at this, and he is now in the midst of a study and will issue a policy, I think, reasonably soon, and it's one of the things that John can follow during this next year, to see to it that the certification policy is consistent throughout all of the centers and, hopefully, more efficient.

Mr. VOLKMER. Have you all looked at the SRB's, as to make an evaluation on their reliability?

Mr. HAWKINS. Yes, we've done that. We have not made a study that comes up with reliability numbers. We think that's the task of NASA to do that and then have us review how they went at it. But the fact is that we have looked at the details of the solids and have followed very closely the perturbations in their performance, and have made some simplification suggestions. I think the actual solid propellants themselves, the nozzles and everything else, are probably the most reliable of the whole system. You can find the problems in the recovery system that have already showed up because of their complexity. I think the chances of hazard are probably higher in the control systems, for instance, in the APU's that are in the solids, than they are in the solids themselves. And so I believe that they have approached the solids and are approaching the filament wound solid with a conservatism that is commendable. And so I think that the calculation of reliability may be more in the systems that support the solid that would be more pertinent

than the solids themselves. Sey, do you want to make a comment on that?

Mr. VOLKMER. Well, let me bring up my point of concern and see if you see any concern with it. Yesterday, in going over this—it all goes back to what happened to the two PAM's thus far during the flight of the shuttle. At least right now the theory as to what happened to the PAM's goes back to the use of solids and back to the nozzles and the possible use of the type of material in the nozzles. Even General Abrahamson yesterday said it's not just a national problem, but an international problem, at least a concern as to the use of the composite materials, and that it needs to be looked into.

Mr. HAWKINS. Well, there's a whole variety of composite materials, too. There are materials used in the cases and the materials used in the nozzles.

Mr. VOLKMER. Now we're talking about the nozzles now. I want to stick with that.

Mr. HAWKINS. Well, the nozzle materials are certainly the source of lots of concern, because of the fact that the processing is very difficult to cover and follow, and the materials that—the materials' consistency in those nozzles is difficult to ascertain ahead of time, and almost impossible to inspect afterward. So there's a lot of state of the art left to go on that, but the fact of the matter is that we've flown an awful lot of solids and we've run an awful lot of testing with nozzles of that variety, and I think NASA's conservatism on their main booster is going to be the saving grace there. Now you must recognize that the failures that have taken place on these upper stages are failures in nozzles and powerplants, for that matter, which have been designed substantially less conservatively than the main booster rockets on the shuttle, and that's—they're reaching for performance there, whereas NASA recognized the fact that the real importance on the solid rocket boosters for the shuttle itself—they had to have a reliable booster before performance, because you've bought the farm if one of those main solid boosters fails.

Mr. VOLKMER. Well, we didn't have a failure on one of the SRV's, but, if my memory serves me correct, we had a—after return of it and inspecting of it, found a defect, I believe, in one of them. I believe it was on——

Mr. HAWKINS. Yes.

Mr. VOLKMER [continuing]. STS–8.

Mr. HAWKINS. Yes, and we looked at that very thoroughly, and it demonstrates the conservatism with which they approached this. They had enough material to withstand a failure in that nozzle, whereas in a high-performance rocket they wouldn't have had and it would have burned through, which may have been exactly what happened in the recent upper stages. So this was unpredictable in a way, but the conservatism of the design made the thing last for its full duration. So I think that this is a demonstration of how they've approached it, rather than a real worry. But we certainly must worry when we find something that doesn't happen quite the way it was supposed to happen.

Mr. VOLKMER. Now if the Panel does have time, I would appreciate it if they would at least review the—NASA's actions in regard

to reevaluating the nozzles and the materials, et cetera, and the processing, and how it comes about.

Mr. HAWKINS. For the main rocket?

Mr. VOLKMER. Yes, for the main SRB. Now what would you say are the primarily weaknesses that are inherent in NASA's current organization supporting an operational shuttle program?

Mr. HAWKINS. We have suggested in times past, and continue to suggest, that they try to separate the organization that runs the operation of the shuttle from the development organization. We have used, and we use it cautiously, the analog of the airlines versus the manufacturing industry for aircraft, where the airlines know what they need to do from the standpoint of an operational standpoint and they apply the requirements on the manufacturer to fix the darned airplane. That kind of a thing doesn't exist in NASA at the moment because the operational folks are almost the same as the development folks. So we have suggested that they have an operational head in headquarters who has the authority and runs the centers, if you will, that do the operations, and he has his own sustaining engineering organization and that they impose changes on the development organization, and they can criticize changes and actually refuse to take them for performance changes if, indeed, they think that it's not going to help them operationally. It will give them an organization that says, I want a change because this thing will only be used 5 times, and I need to have it used 100 times. There's no one in the organization that's pounding on the table for that kind of a change, and we think it's not too early—in fact, we think it wasn't too early a couple of years ago—to set up that kind of an organization.

Mr. VOLKMER. Do you think also—because you testified in your statement on the question of maintenance——

Mr. HAWKINS. Well, they would be responsible for how often you have to maintain something. They will take their operational experience and set up these programs. And if they have an operational experience, they'll estimate them and set them down so that it's incorporated in the schedule.

Mr. VOLKMER. When you speak of a maintenance program, just so I understand and know what you're telling me, are we talking about a—in other words, a standardized, basic list of items that should be checked and tested after each flight or between flights during the turnaround time, and things like that?

Mr. HAWKINS. That's right. You set up a standard for each one of the elements of the shuttle, including the whole shuttle. When do you shut it down and just go over the whole thing, just like you do with an aircraft every once in a while. You take it out of service and you inspect it thoroughly and then put it back. You recertify the airplane. That ought to be scheduled, and we don't find any signs of anybody doing this as an overall program. You have to have it before you can order the spares, it seems to me.

Mr. VOLKMER. Now what safety issues do you think will become more prominent when the shuttle flight rate reaches the 24 a year, especially if we have, let's say, only 4 shuttles in operation? Can you give us some ideas?

Mr. HAWKINS. Well, I don't think you can isolate any one particular part of the shuttle that's going to get into difficulty. We've

already isolated those parts, I believe, for instance, the turbomachinery and the main engines. If it has to be replaced every flight or every third flight, that is a very poor kind of an operation when you're trying to turn it around and get 23 or 24 flights a year. So those have to last longer, and that's why I think they need to have redesigns. I think the APU is a subject of a certain amount of difficulty as far as turnaround time. If we have already found out that an APU actually is vulnerable to age, that part ought to be fixed, and we ought to be sure that we can run an APU and not have to run it in between flights every time to be sure it will run next time. That is going to be the next one, I believe. And, of course, if they fix the landing gear, then maybe it will last for a while, but they've had to replace the brakes on every landing so far. So those kinds of things are the kinds of things you run into on repetitive programs. Now the real boobytrap on repetitive programs is that the shuttle will not get the attention it gets on turnaround. It's gone over with a very fine-toothed comb on turnarounds today because there's time available to do it, and they're taking the time. But when you try to get the shuttle rate up, you're going to have to be sure which parts of that shuttle you can afford to ignore in between flights.

Mr. STEWART. Willis, I might just add, I think the other thing which I think the shuttle processing contractor is aware of is just the attitude of the people doing the work. As it becomes more repetitive and routine, there's a tendency not to be as careful and attentive as you were in the early part of the program. And so really attentiveness to work and good morale among the workforce, enthusiasm with what they're doing, pride in their work—all those sort of attitudes that are not technical at all but sort of psychological become very important.

Mr. VOLKMER. There is a tendency to overlook little things after a while.

Mr. STEWART. Yes. They become very important, like the same kind of problem that I encounter in my regular line of work, in the running of nuclear plants. People have got to be attentive, on their toes.

Mr. VOLKMER. Would it make any difference in this evaluation if we had an additional shuttle, say you had five, to make the 24 or 25 that we need?

Mr. HAWKINS. Another shuttle would certainly help the scheduling to rates like this, because you then would have enough flexibility to actually take a shuttle out of the cycle in order to do one of these maintenance tasks. Right at the moment you'd find it difficult to pull a shuttle out of the program for any length of time and still make the schedule. And then the real problem, I think, that has to do with an extra shuttle is that one of these days we're going to have an incident that's going to lay up a shuttle for a substantial amount of time, and if that takes place, then the schedule is going to have to respond because it doesn't have enough flexibility in it.

Mr. VOLKMER. Yesterday, in discussing this very thing a thought came to mind from someone else to me that I think is very appropriate, and I'll mention it at this time. If you had a serious accident to a shuttle—whether let's say a landing gear broke on land-

ing or a part of the flap burned off or something—would you send up another shuttle on time before you found out what caused it and had replaced it?

Mr. HAWKINS. The agency has met up with that problem already in a number of cases on any of their failures. And so we have watched each one——

Mr. VOLKMER. But those are minor basically, like APU, and——

Mr. HAWKINS. That APU isn't exactly minor.

Mr. VOLKMER. Well, at least in discussing it yesterday with General Abramson, he felt that basically they're looking at the materials and to the parts that had the corrosion, but also he feels that, by going through a purging process, that they can probably alleviate some of that.

Mr. HAWKINS. Oh, we can. We can. And what they're doing is rational, but the APU, you've got to understand what's wrong with it before you start using it again. And I think they do understand it, and they've done that thoroughly each time. Now if an accident takes place in which you have damaged it very severely, damaged the shuttle, then it's going to take some time to put it back together again, because it would be a new operation for them completely, and there has been no planning for that. You can't plan for an accident.

Mr. VOLKMER. Again, let's go back to my other question. Would you go ahead and send up another shuttle?

Mr. HAWKINS. If you knew what caused it, yes. And if you did—we—the panel has never really blown the whistle on NASA except once, and they responded and it was worthwhile responding. So I think that the panel worries about that kind of a thing and worries about it more than anything else, and we're always involved on those kinds of decisions. So I believe that you can be assured that if we need to blow the whistle, that NASA will listen.

Mr. VOLKMER. I hate to take up more time. Do you have any questions? I have one more before——

Mr. LOWERY. Go ahead, Mr. Chairman. I just have a couple, but go ahead.

Mr. VOLKMER. Mr. Brizendine—

Mr. BRIZENDINE. Brizendine.

Mr. VOLKMER. Brizendine.

Mr. BRIZENDINE. Right on.

Mr. VOLKMER. I'll get it one of these days.

Mr. HAWKINS. Briz. [Laughter.]

Mr. VOLKMER. Do you plan in the future to look at any of the safety concerns with regard to the Centaur program, shuttle-Centaur?

Mr. BRIZENDINE. Yes, those are definitely in the plans for this year.

Mr. VOLKMER. I have no further questions. I'll recognize the gentleman from California, Mr. Lowery.

Mr. LOWERY. Thank you, Mr. Chairman. One of my questions related to safety on Centaur as well. Have you looked at it thus far?

Mr. HAWKINS. Yes. The answer is yes. We had a very thorough review of the Centaur program on their first design review, and we've followed it since. And then we've got darned near one of the

inventors of it right here. Sey, do you want to make any comments on where you think we stand on that?

Mr. HIMMEL. Well, I think that——

Mr. HAWKINS. Sey Himmel.

Mr. HIMMEL. The people who have been involved in the Centaur, both at JSC and at Lewis, have been very much aware of the problems of installing a cryogenic propellant system inside the shuttle cargo bay and have conducted very thorough studies of the problems that are presented and also the solutions thereto. As a matter of fact, I believe the middle of next month there is the level 2 shuttle-Centaur safety review at JSC, which is essentially the culmination of the decisionmaking process on how to provide the safety. Both I and Mr. Elverum, who is also a member of the panel, have sat in on sessions having to do with the design of the Centaur and the precautions that are being taken. And, to the best of our ability, we believe that the questions are being addressed in a very sound and thorough fashion, and that there will be no safety hazard residual when they get done with the design process. Of course, there are always things that can be overlooked, but the testing programs which are envisioned should catch them and should provide a reliable upper stage for the shuttle system.

Mr. LOWERY. Do you agree with the simplifications done on the abort system?

Mr. HIMMEL. Very much so.

Mr. HAWKINS. As a matter of fact, we're one of the inciters to this. When we first looked at the first design program, it looked like they were imposing more safety requirements on Centaur than they were on the shuttle, and that it would take some simplification because complexity is a safety hazard in itself.

Mr. LOWERY. What about looking at safety on IUS? Are you at all optimistic on progress made in resolving some of those problems?

Mr. HAWKINS. Well, I think the IUS—and Sey may want to make a comment on that—I think the IUS safety problems haven't been impacted at all by its failure. It's the kind of a thing that, from the standpoint of carrying it around and launching it, the kind of failure that occurred to it wouldn't hazard the shuttle. We don't look at the—we don't worry about anything that doesn't affect the safety of the shuttle, in effect, and as near as we can tell, it's still safe to carry around just the way it is.

Mr. LOWERY. There are not problems with safety on IUS?

Mr. HAWKINS. That's right.

Mr. HIMMEL. The problem is one of reliability, and the failure which occurred is basically the same materials problem, or the sort of materials problem that manifested itself apparently on the PAM-D, the PAM failures, and it's just a question of understanding the design and where the pitfalls are, and also the processing, which is very critical because, to use an expression that I've used in the past, "the little old winemaker has to be there and know what he's doing," or else you're not going to get the product you think you've got.

Mr. LOWERY. Getting back to the shuttle itself, will all the development work essentially be done by 1988?

Mr. HAWKINS. I don't think the development work is over on the Lockheed L-1011, and we're out of the business. But the fact of the matter is that——

Mr. LOWERY. It's a great aircraft.

Mr. HAWKINS. Well, I'm sure John feels the same about the DC-10, and it's a great aircraft. But the fact of the matter is that for all of the original outline of an R&D program, I think it will be complete by 1988, but by that time they will want to carry more payload and they'll start some other development programs, and——

Mr. LOWERY. But with the schedule now, you don't——

Mr. HAWKINS. I don't see——

Mr. LOWERY [continuing]. Missing that 1988——

Mr. HAWKINS. They seem to have everything planned to do the things we need to be doing.

Mr. LOWERY. Are there any additional safety issues associated with an extended duration orbiter?

Mr. HAWKINS. Oh, certainly, there are many safety issues with an extended duration, having mostly to do with the crew support gear and the amount of residual energy you've got left to reenter. And if you have a chance of losing some of your energy that you need to reenter, or, for that matter, the problem of not being able to get online the gear you need to reenter—as, for instance, the APU's— those would be--would have to be looked at thoroughly, I think, before we multiplied by a factor of more than two or three. But the fact is that they were originally designed to stay up there for twice the period of time or more than they've been designed for already, so I don't see any outstanding hazard that has to be attacked if they're going to stay in the air for two or three times as much as they do today.

Mr. LOWERY. Thank you. Thank you, Mr. Chairman.

Mr. VOLKMER. I'd like to address, before we adjourn, one other question that I'd like Mr. Brizendine and his group to look at in the future. You did address in your statement to me, which is part of it, and that is the problem of logistics and the one centralized person, but we also looked at it a little bit yesterday as to where it's to be located as far as a logistics center, especially for parts, et cetera, and the availability of those, and whether that should maybe be at Kennedy or wherever, for the purpose of making sure that those things are available that need to be available.

Mr. BRIZENDINE. We'll look into that as part of the logistics support. You're specifically interested in the support center for the logistics support?

Mr. VOLKMER. Yes, for the logistics support and personnel, also. I think that needs to be looked at— the question of whether we have enough, a sufficient number of logisticians available and where they're located.

Mr. HAWKINS. When we talked to NASA about this problem in times past, we have never said it had to be in headquarters. It just has to have the headquarters authorization that they are headquarters people wherever they are located. It might make some sense to put them at a center and turn the center into the operations center and give it the authority to set up these things. So I

don't think we tried to telegraph where we think it ought to go, just as long as it exists.

Mr. VOLKMER. I have no further questions. I wish to thank all of you for being here today and being very helpful, again, as usual. And it's nice to have what I call an objective panel basically reviewing the safety features, and it's very helpful to us as we look into it. As I say, as a result of this, I'll be writing a letter to Mr. Beggs today or tomorrow, anyway. So I hope to get some answers. We appreciate it. With that, the committee will stand adjourned. Thank you very much.

[Whereupon, at 12:49 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

1985 NASA AUTHORIZATION

TUESDAY, FEBRUARY 28, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 1:07 p.m., in room 2325, Rayburn House Office Building, Hon. Harold Volkmer (chairman of the subcommittee) presiding.

Present: Representatives Volkmer, Nelson, Andrews, Brown, Lujan, Chandler, Bateman, and Walker.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

Today, the Subcommittee on Space Science and Applications continues our fiscal year 1985 NASA authorization hearings. Our witnesses today will be providing testimony related to the space transportation system.

Our first witness will be Mr. William T. Hamilton who chaired a national academy panel to assess constraints on space shuttle launch rates.

Our second witness will be Mr. Norman H. Fischer, manager, space systems section, Battelle's Columbus Laboratories, who will discuss Battelle's studies and views of shuttle flight rate projections, the need for a fifth shuttle orbiter, and requirements for an extended duration orbiter capability.

Our final witness will be Mr. Phillip K. Salin who will discuss his personal views on NASA shuttle pricing and cost-accounting policies.

Mr. Hamilton, before proceeding, I would first like to recognize the gentleman from New Mexico for an opening statement.

Mr. LUJAN. Thank you very much, Mr. Chairman. I believe we will hear some very interesting and valuable testimony this afternoon. When considering the space transportation system, we have a strong and successful program to support. The President's budget request shows that the administration is also a strong supporter of the shuttle, and certainly this subcommittee has historically been enthusiastic. As we look into the future, there are several options to be considered for the space transportation system. These include extended duration orbiter capability, the procurement of a fifth orbiter, the interest in developing a next generation vehicle, the need for a shuttle marketing program, and the future role of the ELV's.

In considering these options, there are several factors to evaluate. First, we need to examine the present capability to support the

24 flight per year rate, as well as future increases. Hopefully, Mr. Hamilton will give us an insight into that issue.

Second, we need to examine projections for the future demand. This is a mixed picture, from my perspective, anyway. During the past few years, we have seen the actual number of launches and payloads consistently turn out to be much lower than projected levels. This is in contrast to the projections which show a strong growth in demand. For instance, of the 50 payloads scheduled for 1987, one-fourth are for science missions. By the next year, the proportion of science payloads increases to one-third.

Clearly, there seems to be a strong growth in science missions. The demand for commercial satellite launches seems to be more unpredictable, however. They account for half the launches in 1987 and a little over one-third for the fiscal year of 1988. This reminds me of the dilemma faced by the electric utilities in forecasting demands. There have been studies done of the utility program that conclude that adding smaller increments, in this case smaller size powerplants, also allow the utilities to follow their demand growth curve more closely with less risk and, I should say, more cost effectively. I recognize that the space transportation system is not the same as a utility, but the general principle still has some validity.

We may also be able to deal with uncertainty in the demand growth very effectively with smaller increments by taking advantage of the commercial ELV industry that is eager to get started. This is not to suggest, however, that we no longer rely on the shuttle as our primary launch system, but that we have a strong backup capability.

Last week we heard testimony that showed that the number of orbiters is not the crucial issue in maintaining a U.S. launch capability, because in case of an accident, NASA would not fly any shuttles until the cause was determined and the necessary changes made in the orbiter. If no orbiters are flown, it doesn't matter if there are 3 or 4 or 5 or even 10.

It is important that we maintain a mixed fleet to assure that we have U.S. launch capability, and thus can continue to be competitive.

Finally, we much consider the cost to the taxpayers. We have already invested a tremendous amount of the taxpayers' dollars for the space transportation system. The shuttle is the jewel from this investment. We will want to use this asset as wisely as possible, but if we lose money on every launch and then adopt a marketing policy to increase those losses, this may not be a very good buy from the taxpayers' point of view.

If NASA adopts policies that prevent the ability of commercial ELV industry to provide backup launch capability, this also may not be a good buy for the taxpayer.

However, as I have said before, Mr. Chairman, we cannot afford to be uncritical supporters of the space transportation system, but we also cannot afford not to be supporters.

I am hoping that today's witnesses will give us some useful insights in considering these options.

I thank you very much, Mr. Chairman.

Mr. VOLKMER. Thank you.

Mr. Hamilton, your statement which you have furnished us will be made a part of the record. It will be included in the record in full. You may either review the statement in full or summarize, however you so desire.

Thank you very much.

STATEMENT OF WILLIAM T. HAMILTON, CHAIRMAN, PANEL TO ASSESS CONSTRAINTS ON SPACE SHUTTLE LAUNCH RATES, NATIONAL ACADEMY OF SCIENCES, NATIONAL RESEARCH COUNCIL

Mr. HAMILTON. Thank you, Mr. Chairman, and members of the subcommittee.

I am pleased to respond to your invitation to present the results of a National Research Council study, "An Assessment of Constraints on Space Shuttle Launch Rates," that is the number of launches per year. I have prepared a complete review of the study results for the record and would like at this time to discuss the major findings and highlights of the report.

The National Research Council panel was charged with providing, No. 1, an estimate of the range of number of annual space transportation system, that is, space shuttle, flights possible, given both a four- and a five-orbiter fleet, all accounting for normal turnaround times and contingencies.

No. 2, an overview of the capabilities needed to support flight rates of 18, 24, 30, and 40 launches per year, along with a survey of known constraints or limiting factors.

No. 3, information regarding the external tank facility modifications and requirements for external tank production necessary to meet the above flight rates as well as the time and cost involved in meeting those requirements.

In assessing constraints on space shuttle launch rates, the panel considered the components of the space shuttle and their potential capabilities to meet various flight rates along with the supporting facilities and services. The basis for estimating launch rates, hardware requirements, and other capabilities was limited because there is little experience in space shuttle turnaround or major orbiter maintenance and the facilities at Vandenberg Air Force Base are not yet operational.

Therefore, the following assumptions were made in providing the panel's assessments: No. 1, the equivalent of one orbiter will be dedicated to missions launched from Vandenberg Air Force Base; No. 2, no contingencies will occur that will take an orbiter out of service beyond the planned 5 months for scheduled maintenance after every 15 to 25 missions. The difference is dependent upon whether you use an optimistic or a conservative estimate; No. 3, mission durations will average 5 to 7 days; No. 4, work will be accomplished on a 5-workday, three-shift schedule, allowing weekends to recover from any schedule delays.

The panel reviewed each of the elements that support the operation of the shuttle, the production of external tanks, the recovery and refurbishment of the solid rocket motors and boosters, the ground processing of the orbiter, including its main engines and subsystems, the integration of the orbiter, external tank, and solid

rocket booster into a space shuttle preparatory to movement to the launch pad, and the logistics systems that support each of these operations.

Mr. Chairman, my full testimony contains detailed time estimates for each step in the turnaround process for the 1990 timeframe. We arrived at an optimistic estimate of 6.6 average flights per year per orbiter, based on a 28-day average ground turnaround, a 5-day mission, and major maintenance only once every 25 flights.

Our conservative estimate, based on a 40-day turnaround, 7-day missions, and major maintenance once every 15 missions was 4.6 missions per year per orbiter. Somewhat lower launch rates are expected at Vandenberg.

The panel thus estimated the range of the number of annual space shuttle flights in the 1990 timeframe to be between 17 and 25 flights per year for a 4-orbiter fleet and between 22 and 31 flights for a 5-orbiter fleet.

We assessed the capabilities of the space shuttle components to meet the various launch rates, again presuming a 5 to 7-day mission duration. That is presented in the viewgraph. Several conclusions may be drawn from this figure.

No. 1, for 24 missions per year, a minimum of 4 orbiters is essential. In the event of extended mission duration, more frequent repair, longer overhaul periods, or contingencies that incapacitate an orbiter for a prolonged period, the number of yearly launches will be reduced.

No. 2, the external tank appears to be the only major component of the space transportation system for which firm planning was in place to attain levels of 24, 30, and 40 flights per year.

No. 3, solid rocket booster requirements must be derived from experience, but our estimates incidate that insufficient stocks of booster aft skirts, aft propulsion segments, and forward skirts were planned. Planning was not in place and procedures remain to be developed to enable the solid rocket boosters to meet NASA's mission model, that is, 24 launches in 1988, 30 launches in 1990, and 40 in 1992. In addition, because of the extent of damage suffered by the forward skirts of the solid rocket booster in recovery from the ocean, the lack of experience regarding life expectancy of many booster parts, as well as a mixed inventory including both metal and filament wound booster casings, the panel encouraged a heavy spares policy.

No. 4, a space shuttle main engine quantities plan for operations and spares were considered marginal to support 24 flights per year. However, not even that rate would be realized without a major spares policy, particularly in the high pressure liquid hydrogen and liquid oxygen turbopumps. The panel noted that the main engine should continue under development for a number of years and that the turbopumps may have to be redesigned for longer life.

Major contingencies which might affect flight rates are not included in these estimates. Such contingencies include main engine component failures, solid rocket booster limitations, the failure of an orbiter major structural element, such as the landing gear, reduction or loss of control power from the auxilliary power units, or diverted ocean landings. Other possible occurrences with major schedule impact would include loss of a major space shuttle main

engine test firing facility, unexpected rain damage to the shuttle thermal protection system, failure of the landing gear to extend, or even a shuttle ditching. While these contingencies cannot be quantified, and their probability is reasonably remote, space shuttle system capabilities will be reduced below the Panel's estimate by any such occurrence.

In addition to the components of the space shuttle, the development of the Space Transportation System into an efficient system requires controlled expansion of its support facilities. We prepared a matrix indicating the major capabilities required to support Space Transportation System operation. That is now shown on the viewgraph.

The existing and already funded facilities at the time of the report would accommodate about 18 launches per year; 24 launches per year would require additions to the mobile launch platform, processing and storage facility, and the vertical processing facility. To achieve 30 launches per year, significant additions will be required for most of 11 facilities and all need additions to reach a 40 per year launch rate. It should be noted that many of the facility requirements are directly dependent upon the shuttle's turnaround time.

Since the long term spares and maintenance program requirements must be based upon experience, it was not surprising that a coherent spares and maintenance program was just developing. The Panel members believe strongly that operation of the Space Transportation System in an efficient and routine manner demands that emphasis be placed on providing adequate spares and on a systematic maintenance and logistics policy. Inevitably, such a program must address the need for retaining elements of the orbiter production line to permit reasonable replacement of all key components as required. This seems particularly critical for the production of very long leadtime elements for the orbiter structure and systems.

The most prominent constraints to launch rates in the early growth of the Space Transportation System as an operational system may manifest themselves not as a shortage of major investment items such as the external tank or the solid rocket booster, but rather as an inability to provide timely repair or replacement of numerous lesser flight system components needed to sustain launch rates.

The Panel was particularly concerned about the implications of shutdown of production of the orbiter components and the attendant loss of skills, tooling and contract manufacturing capabilities in general. Reinitiation of such production lines at a later date becomes a formidable task. Not only will costs be higher but production leadtimes will be considerably longer. For example, it is estimated that the leadtime for an orbiter wing construction increases from 6 months to 36 months, and there may be a need to requalify a high percentage of the shuttle elements.

Mr. Chairman, we believe the success of the space shuttle's operational future is dependent on the timely availability and proper functioning of an extensive and complex array of facilities, components, and services requiring long-term planning and honest cost effectiveness. At the time the report was published, five flights had

been completed. That number has now doubled, but I believe the conclusions of our study generally still remain valid.

Mr. Chairman, I will be pleased to answer any questions you may have.

[The prepared statement of Mr. Hamilton follows:]

Statement of
WILLIAM T. HAMILTON
CHAIRMAN, PANEL TO ASSESS CONSTRAINTS ON
SPACE SHUTTLE LAUNCH RATES

National Academy of Sciences/National Academy of Engineering
National Research Council

before the

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES

Tuesday, February 28, 1984
Room 2325, Rayburn House Office Building

Mr. Chairman and Members of the Subcommittee:

I am pleased to respond to your invitation to present the results of a National Research Council study, An Assessment of Constraints on Space Shuttle Launch Rates. The study was requested jointly by the House and Senate Appropriations Committees in late 1982 and completed in April of 1983. Before I summarize the study findings, you may want to know something about the group which prepared the report. In selecting the panel to conduct the assessment we thought that persons with the required knowledge about the space transportation system (STS) might also have some preconceived opinions; therefore, we tried to balance these apparent biases in the composition of the group in order to obtain the most objective review possible. In addition to knowledge about the STS, we sought expertise of the nature gained in managing routine turnaround and maintenance of a major airlines as well as logistics expertise in supplying a sophisticated system such as the STS and in moving large hardware long distances. The membership of the panel was as follows:

WILLIAM T. HAMILTON, Consultant to the Boeing Company/Retired Vice President-Chief Scientist, Boeing Military Airplane Company, Chairman

JOHN G. BORGER, Consultant/Retired Vice President and Chief Engineer, Pan American World Airways

KELLY H. BURKE, Chairman of the Board, Stafford, Burke and Hecker, Inc./Retired U.S. Air Force Deputy Chief of Staff, Research, Development and Acquisition

WILLIS M. HAWKINS, Senior Advisor, Lockheed Corporation/Retired Senior Vice President, Lockheed Corporation

BENJAMIN HUBERMAN, Vice President, The Consultants International Group, Inc.

CHRISTOPHER C. KRAFT, JR. Consultant/Retired Director, NASA Lyndon B. Johnson Space Center

BRYCE POE, II, Consultant/Retired Commander, U.S. Air Force Logistics Command

WILLIAM A. ANDERS, Member, NRC Committee on NASA Scientific and Technological Program Reviews, Ex-Officio Member of the Panel

EUGENE E. COVERT, Member, NRC Committee on NASA Scientific and Technological Program Reviews, Ex-Officio Member of the Panel

Figure 1

The panel was charged with providing:

(1) An estimate of the range of number of annual STS flights given both a four- and five-orbiter fleet, accounting for normal turnaround time and contingencies,

(2) An overview of capabilities needed to support flights of 18, 24, 30, and 40 launches per year with a survey of known constraints,

(3) The following information regarding production of the STS external tank (ET): an estimate of facility modifications and requirements for ET production to meet the above flight rates; an etimate, based on available data, of the costs of the above ET facility modifications and tooling, including any added costs in going incrementally to higher production rates; and an estimate of the date ET production would be available to support each flight rate.

As your committee is well aware, Mr. Chairman, responsiblity for the STS is shared among a number of NASA centers and NASA headquarters. The following diagram indicates responsiblities for various orbiter components, as well as the contractors for major hardware elements (Figure 2).

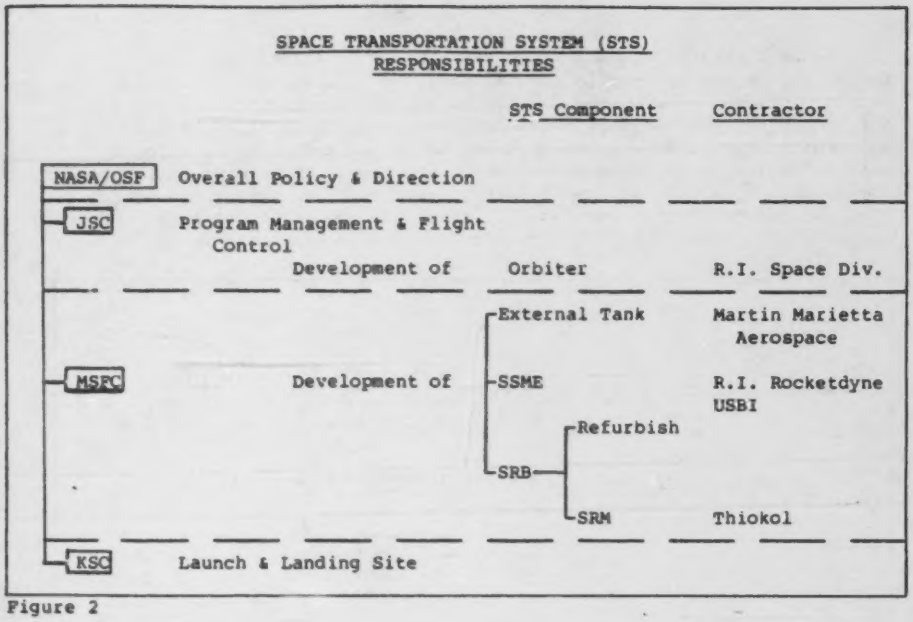

Figure 2

Although an original focus of the study was production of the external tank, it soon became apparent that this component of the STS was among the least likely to cause problems; therefore I will concentrate today on the panel's findings concerning potential turnaround times, or flight rates.

In assessing constraints on space shuttle launch rates, the panel considered separately the components of the space shuttle and their potential capabilities to meet various flight rates and the supporting facilities and services. The basis for estimates of launch rates, hardware requirements, and other capabilities was limited because there is little experience in space shuttle turnaround or in major orbiter maintenance, and the operations as Vandenberg AFB are still in the planning stages. Therefore, the following assumptions were made in providing the panel's assessments: (1) the equivalent of one orbiter will be dedicated to VAFB-launched missions, (2) no contingencies occur that would take an orbiter out of service beyond the five months scheduled maintenance after every 15 (conservative estimate) to 25 (optimistic estimate) missions, (3) mission duration averages five to seven days, and (4) work is accomplished on a five-workday, three-shift schedule, allowing weekends to recover from schedule delays.

SHUTTLE TURNAROUND

The phases in the turnaround process--considering a landing at the Kennedy Space Center shuttle landing facility to the next launch--include: tow of the orbiter to the Orbiter Preparation Facility for inspection, maintenance, and horizontal cargo loading if required; movement to the Vehicle Assembly Building for mating with the external tank and solid rocket boosters on the Mobile Launch Platform; roll out of the shuttle to the launch pad for servicing; vertical cargo loading if required; checkout; and launch. Optimistic and conservative time estimates for each step in the turnaround process are shown in the following figure:

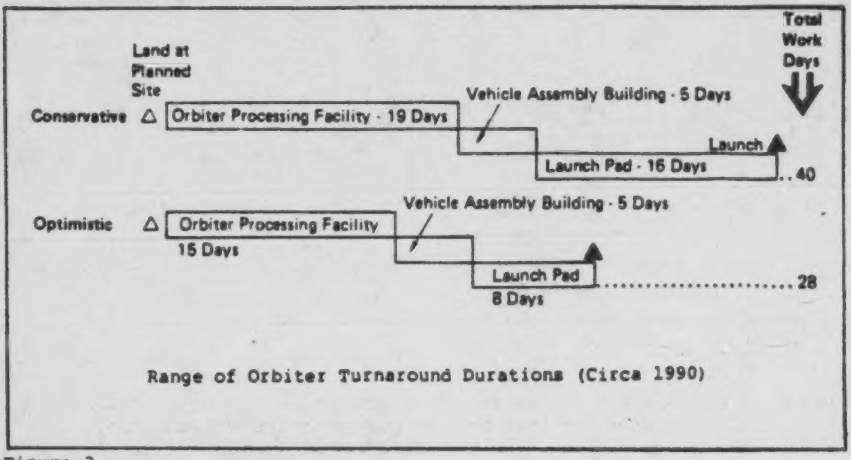

Figure 3

The panel projects that the average flights per year per single orbiter will be 4.6 to 6.6 as shown in Figure 4.

Table I ORBITER FLIGHT CAPACITY

Estimate	Ground Turnaround	Average Mission Duration	Major Periodic Maintenance Downtime	Average Flights per Year per Orbiter 5/3[3]
Conservative	40 Work Days	7 Days	15/5 Mo.[1]	4.6
Optimistic	28	5	25/5 Mo.[2]	6.6

[1]After every 15 flights an Orbiter is taken down for 5 months for major periodic maintenance.

[2]After every 25 flights an Orbiter is taken down for 5 months for major periodic maintenance.

[3]Workweek is 5 days and 3 shifts per day.

Figure 4

Based on the assumptions mentioned earlier, the panel thus estimated the range of the number of annual STS flights in the 1990 time frame to be 17 to 25 flights per year for a four-orbiter fleet and 22 to 31 flights for a five-orbiter fleet (Figure 5):

Table II SPACE SHUTTLE FLEET CAPACITY

	Total Flights per Year 5-Day Workweek, 3 Shifts	
Estimate	4-Orbiter Fleet	5-Orbiter Fleet
KSC Launch Estimates		
Conservative	18	23
Optimistic	26	33
One Orbiter Equivalent at VAFB		
Conservative	17	22
Optimistic	25	31

Figure 5

The estimated capabilities of components of the space shuttle to meet various launch rates are shown below (Figure 6):

Annual Launch Rate	Orbiter Fleet Size			Space Shuttle Main Engine	Solid Rocket Booster	External Tank
	4	5	6			
18	OK	OK	OK	OK	M[1]	OK
24	M	OK	OK	M[1]	X[2]	OK
30	X	M	OK	X	X	OK[3]
36	X	X	M	X	X	OK[3]
40	X	X	X	X	X	OK[3]

M = marginal
X = impossible or highly improbable
[1] with existing production/refurbishment facilities
[2] options for SRB being studied
[3] five plans exist to meet increased production requirements
*Longer missions and/or major mishaps decrease the potential number of yearly launches

Capabilities of STS Components to Meet Various Launch Rates
(5- to 7-Day Mission Duration)

Figure 6

As you can see, for 24 missions a year, a minimum of four orbiters is essential. In the event of extended mission duration, more frequent repair, longer overhaul periods, or contingencies that incapicate an orbiter for a prolonged period, the number of yearly launches would be reduced below 24. You will note that at the time we completed the study, planning was not in place and procedures remained to be developed to refurbish the solid rocket boosters (SRBs) to meet the NASA mission model (24 flights by 1988; 30 by 1990; and 40 by 1992). In addition, because of the extent the aft and forward skirts of the SRB may be damaged in recovery from the ocean, the mixed inventory of metal and filament wound casings, and the lack of experience regarding life expectancy of many SRB parts, the panel encouraged a heavy spares policy for the SRBs. Regarding the space shuttle main engine (SSME), quantities planned for operations and spares were considered barely marginal to support 24 flights a year by 1990. But we did not expect to reach that rate unless a major spares program were initiated, particularly for the high pressure liquid hydrogen and liquid oxygen turbopumps. The panel stressed the fact that the SSME should continue under development for many years and that the above turbopumps may have to be redesigned for longer life.

As I indicated earlier, major contingencies which might affect flight rates are not included in these estimates. Such contingencies include main engine component failure, solid rocket booster limitations, the failure of an orbiter major structural element, reduction or loss of control power (specifically, failure of one or more auxilliary power units), or diverted landings. Other occurrences with major schedule impact would include loss of a major test firing facility for the main engine, unexpected rain damage to the shuttle thermal protection system, failure of landing gear to extend, or even a shuttle ditching in the ocean. While these contingencies cannot be quantified, it must be understood that STS capabilities will be reduced below the panel's estimates by any such occurrence.

OTHER CAPABILITIES REQUIRED TO SUPPORT LAUNCH RATES

The panel considered facilities for launch and landing operations, flight operations and training and mission control. Our findings regarding capabilities of existing and planned facilities are summarized in figures 7 and 8. The first figure shows Kennedy Space Center facilities. The heavy line indicates the number of facilities (existing or approved) and their capabilities, while the dotted line shows the most optimistic capability possible.

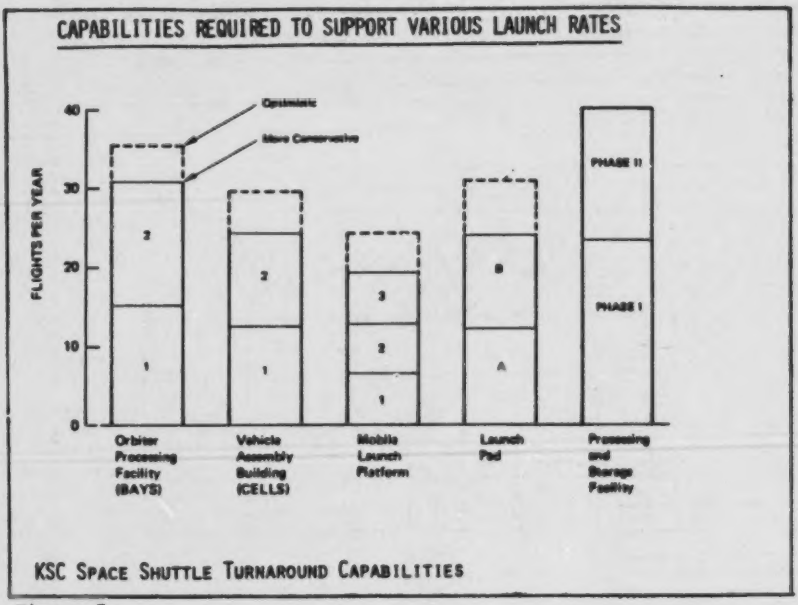

Figure 7

The need for training and mission control facilities is indicated below. Existing facilities are shown in the grey areas, while the dotted line shows the range of potential capabilities.

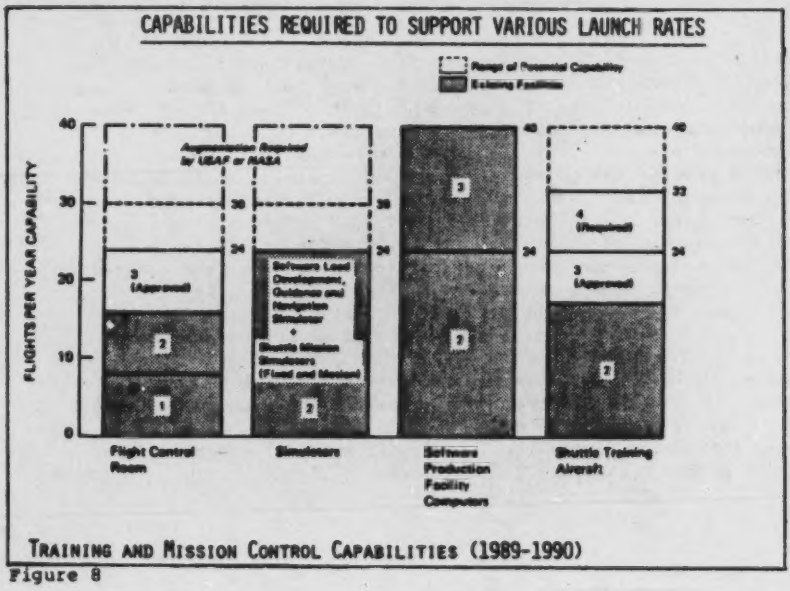
CAPABILITIES REQUIRED TO SUPPORT VARIOUS LAUNCH RATES
FLIGHTS PER YEAR CAPABILITY
Flight Control Room
Simulators
Software Production Facility Computers
Shuttle Training Aircraft
TRAINING AND MISSION CONTROL CAPABILITIES (1989-1990)

Figure 8

The panel developed the following matrix (Figure 9) to summarize the adequacy of the capabilities supporting STS operations. The annual launch rate is indicated in the left column. The circled items represent areas with additional requirements.

SUMMARY OF FINDINGS

Annual Launch Rate	Ground Turnaround: Orbiter Processing Facility	Ground Turnaround: Vehicle Assembly Building	Ground Turnaround: Mobile Launch Platform	Ground Turnaround: Launch Pad	Ground Turnaround: Firing Room	Cargo: Vertical Processing Facility	SRB Refurb.: Processing and Storage Facility	Flight Training: Shuttle Mission Simulator	Flight Training: Shuttle Training Aircraft	Flight Ops.: Flight Control Room	Flight Ops.: Shuttle Carrier Aircraft
18	2	2	2	2	2	1½[b]	1	2	2[d]	2	1[d]
24 (4-5)*	2	2	③[a]	2	2	②	1	2	3	2	②
30 (6)	2	2	③④[a]	2	③	②	②	③[c]	③④	③	②
40 (6-8)	③[f]	③	⑥[a]	③	③④	③	②	③[c]	④	③	②

*Assumed launches from Vandenberg AFB
[f]Circle indicates additional requirement
[a]KSC requirement only
[b]Second bay not completely functional
[c]Includes support to USAF
[d]Does not allow for aircraft loss or disablement

CAPABILITIES SUPPORTING STS OPERATIONS (CELLS OR UNITS)

Figure 9

At the time the report was published, five STS flights had been completed with remarkable success. That number has now doubled, and some problems have arisen. The panel noted that since the long-term spares and maintenance program requirements must be based on experience, it was not surprising that a coherent spares and maintenance program was just developing. The panel members believe strongly that operation of the STS in an efficient and routine manner demands that emphasis be placed on providing adequate spares and on a systematic maintenance and logistics policy. Inevitably, such a program must address the need for retaining elements of the orbiter production line to permit reasonable replacement of all key components as required. This seems particularly critical for the production of very long lead time elements of the obiter structure and systems. The report suggested that the most prominent constraints to launch rates in the early growth of the STS as an operational system may manifest themselves not as a shortage of major investment items such as the ET or the SRB, but rather as an inability to provide timely repair or replacement of flight system components needed to sustain launch rates.

Of particular concern to the panel were the implications of a shutdown of STS production and the attendant loss of skills, tooling, and contract manufacturing capabilities in general. Reinitiation of STS production lines at a later date becomes a formidable task. Not only will costs be higher but production lead times will be considerably longer, e.g., the lead time for an orbiter wing increases from six to 36 months--and there may be a need to requalify a high percentage of the STS sytems.

Mr. Chairman, we believe the success of the space shuttle's operational future is dependent not only on its cost effectiveness, but on the timely availability and proper functioning of an extensive and complex array of facilities, components, and services requiring long-term planning.

I will be pleased to answer any questions regarding the panel's findings, Mr. Chairman.

Mr. VOLKMER. Thank you very much, Mr. Hamilton.

I will now recognize the gentleman from New Mexico for any questions he may have.

Mr. LUJAN. Thank you, Mr. Chairman.

How would all your estimates be affected by taking into consideration missions lasting up to 20 days? You used 5 to 7 in your study.

Mr. HAMILTON. We used 5 to 7; that is correct. If the missions are extended, and there are certainly people who feel that makes lots of sense to use the shuttle occasionally for long missions, it could be done, it will reduce the number of launches we would get.

Mr. LUJAN. Are we being very optimistic in looking at this large number of launches?

Mr. HAMILTON. That wasn't our charge to in the report.

Mr. LUJAN. What do you think?

Mr. HAMILTON. Well, I believe that looking at the statistics, just as you quoted in your statement, that it looks like there are not the number of launches needed as were originally planned for.

Mr. LUJAN. But, if there were needed, and we had 5 to 7 days, are you reasonably optimistic that we could carry on that kind of a schedule or is that rather optimistic?

Mr. HAMILTON. The conservative estimates that we make, I believe, can be achieved. There is certainly a remote possibility that we may have a major item that would put a single shuttle out of service for a prolonged period of time, 6 months or a year, something like that. Those things can always happen. They can happen in commercial aircraft where you lose an engine, the landing gear doesn't come down, something like that. It is not a high probability, but it certainly can happen.

Mr. LUJAN. Maybe the question ought to be those assumptions that you mentioned in the first part of your statement. Do you feel those were pretty reasonable assumptions or were those the assumptions you were told to use in evaluating?

Mr. HAMILTON. We weren't told to use them. We had a Panel that had people with lots of experience. In order to achieve the charge given to the Panel within the time limit, we had to make certain assumptions. Those assumptions were the judgment of the

Panel after consulting with NASA, but these were reasonable things to use for such a study.

Mr. LUJAN. They come from the top in the sense that we would like this conclusion—I am not saying that NASA told you that—we would like so many launchings a year. Therefore, if we are to accomplish that goal, then we will have to assume that they would be 5 to 7 days, that we won't have a vehicle in the garage, so to speak, for more than 5 months, or did they come from the assumptions first, most of them would, as a matter of fact, be 5 to 7 months and then that took you to the conclusions. Which way did it go?

Mr. HAMILTON. Basically, we discussed the length of missions and the things that might control them and push it one way or another. The shuttle itself, with the manned crew, and the kind of census that you normally might send up appeared to have most of their missions would be ones that would be only a matter of a few days. While there certainly might be some that we would send people up for a month, they would be exceptionally few.

Mr. LUJAN. You said that something—that we would kind of be in trouble if we had one laid up for 6 months or a year. In your assumptions, you used 5 months or less. I am trying to find out how you arrived at these assumptions. How could you assume that it was going to be 5 months or less?

Mr. HAMILTON. The 5-month number comes out of the NASA planning, and as planned, their assumption was that every 15 to 20 or 25 flights, it would be necessary to lay up each orbiter when it reached that number of flights to have a thorough inspection and maintenance just as the airlines do every 10,000 hours or something like that on their airplanes to be sure that there are no problems starting. It was estimated that 5 months was a reasonable time to do that kind of a thorough examination and refurbishment of whatever was possibly needing replacing at that time.

Mr. LUJAN. It seems like an awfully long time, doesn't it, 5 months, to go over the whole thing?

Mr. HAMILTON. The shuttle is a very complex machine.

Mr. LUJAN. Yes.

Mr. HAMILTON. And they lay commercial airplanes up for a significant amount of time to really comb through and be sure they are going to be safe. That is part of the reason we have the safety record we have.

Mr. LUJAN. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you.

I now recognize the gentleman from California, Mr. Brown.

Mr. BROWN. I have no questions.

Mr. VOLKMER. The gentleman from Texas, Mr. Andrews.

Mr. ANDREWS. I have no questions, Mr. Chairman.

Mr. VOLKMER. I recognize the gentleman from Washington, Mr. Chandler.

Mr. CHANDLER. I have no questions, either, Mr. Chairman. Thank you.

Mr. VOLKMER. The gentleman from Virginia, Mr. Bateman.

Mr. BATEMAN. We are on a roll, Mr. Chairman. I have no questions either.

Mr. VOLKMER. I am sorry I have got to stop it, though. I have a couple.

Mine has to do with the SRB's and, on the chart, the provision there that if we go to 24 flights a year and, as I understand your chart, the impossible or highly improbable with the present facilities, and reading the full assessment, it appears that the constraints have to do with the logistics in the repairing and reusing the solid rocket motor and the fact that those have to travel all the way back to Utah and then be brought back.

Mr. HAMILTON. That is right.

Mr. VOLKMER. Also, the need for a facility at the Kennedy to refurbish those that are recovered. Is that correct?

Mr. HAMILTON. That is correct.

Mr. VOLKMER. As I understand it, NASA does have out an RFP and is resubmitting the question of having a facility at Kennedy. That would solve that part of it, would it not?

Mr. HAMILTON. I think it would.

Mr. VOLKMER. And the part of refurbishments. Now, what do you see is the need as far as the rocket motors and logistics there?

Mr. HAMILTON. The—it would certainly be nice to have it all done closer to where they were going to be used, but the facilities and the capability is in Utah, and that is where they have, without significant cost increase, that is where they wanted to do it.

Mr. VOLKMER. From reading this, does that mean that we would have to have additional SRB motors on hand, new ones on hand in an inventory at Kennedy?

Mr. HAMILTON. You would have to have sufficient replacement motors in order to let you change out in routine operation. You would have to be able to change out, put a substitute on or something like that. Yes, I think you would have to have them.

Mr. VOLKMER. Because of the timelag of taking them back to Utah and then transporting them-back into Kennedy. Is that correct?

Mr. HAMILTON. Yes.

Mr. VOLKMER. Is there anything else with the SRB's that would cause any problems with the 24-year flight rate?

Mr. HAMILTON. No, I don't think so. I think the report states it as we believed it was. The early recoveries of the booster, booster casings, were damaged significantly more, but NASA has made modifications and changes to limit that damage, so, hopefully, there won't be as much replacement or repair necessary in the future.

Mr. VOLKMER. Now, is it valid, and I read your full report, is it valid to assume that, as the panel did, that no contingencies would occur that would take an orbiter out of service for an extended period of time? In other words, we are not going to have any major problems?

Mr. HAMILTON. That is certainly a debatable item. When you have only got a four or five orbiter fleet, just as with airplanes or anything else, there is always a possibility that one will be done due to some acute area of the weather or an accident, what have you. That happens, and it can happen. We assumed it was a rather remote probability, but it is a definite possibility.

Mr. VOLKMER. Did you make any determination as to if we had an orbiter or lost one or had one down for an extended period of

time what would be the flight rate, assuming we still have one dedicated at Vandenberg?

Mr. HAMILTON. It would drop about 6 flights per year.

Mr. VOLKMER. Would the addition of 1 orbiter, in other words, 5, having an orbiter fleet of 5 add any constraints to 24 flights per year?

Mr. HAMILTON. No, I think it helps you to achieve 24 flights per year.

Mr. VOLKMER. I have no further questions. Does anybody else have any other questions?

Thank you very much, Mr. Hamilton. You have been very helpful and I appreciate your testimony and also the assessment report that we received.

Mr. HAMILTON. Thank you.

Mr. VOLKMER. Our next witness will be Mr. Norman Fischer, manager of the space systems section of Battelle's Columbus Laboratories.

Mr. Fischer, I too wish to thank you in advance for your statement. It will be made a part of the record, and you may either review it in full or summarize, however you so desire. You may proceed.

STATEMENT OF NORMAN H. FISCHER, MANAGER, SPACE SYSTEMS SECTION, BATTELLE'S COLUMBUS LABORATORIES

Mr. FISCHER. Mr. Chairman and members of the subcommittee, it is a pleasure for me to appear before you to discuss Battelle's studies and views of shuttle flight rate projections, the need for a fifth shuttle orbiter, and requirements for an extended duration orbiter capability.

Mr. Chairman, with your permission, I would like to submit my statement for the record and briefly summarize it for you.

First, a few words of background on Battelle and its experience relative to the above topics. Battelle's Columbus Laboratories is a division of a worldwide 7,000 member research organization. The Columbus Laboratory has a staff of approximately 3,000 and is organized into departments as shown on this first chart. The space systems section is part of the defense and space systems department. The space systems section has two decades of experience working for NASA Headquarters, with over 10 years of that being related to shuttle. Our studies for NASA include payload projections, shuttle operations, and shuttle policy methodology. We have produced payload projections for reimbursable customers annually since 1975. This experience is the primary basis for my testimony.

As you know, NASA publishes a payload model for the shuttle on a periodic basis. There are three major components of the shuttle demand model: NASA missions, DOD missions, and other, that is, outside users. In determining flight rate projections, all three of these components need to be considered. NASA missions depend on a variety of factors including NASA's budget and future goals. The DOD demand is also a function of its goals, accomplishments, and budgets. It is not within Battelle's expertise to comment on any NASA or DOD flight rate which is within budget and satisfies or-

ganizational goals, but I will address the third component of the shuttle demand.

The outside users are driven by factors such as economics, other Government agencies requirements, foreign governments, and technology developments. Our projections are for free world demand for space transportation and we make an assessment of how much of the total will be shuttle customers.

Our payload projections include all known non-NASA, non-DOD reimbursable payloads scheduled to be flown by non-Soviet bloc countries with the exception of Spacelab payloads.

In development of our latest model, we made the four following assumptions:

Both Shuttle and Ariane are technologically successful and price competitive.

Two, U.S. commercial ELV's are not considered. Their entry into the market will likely have a negligible effect on the total market demand, but may alter the market share captured by each vehicle.

Three, potential space station impacts are not considered. These impacts can be defined in more detail once a firm space station concept and timetable are established.

Four, there will be no revolutionary technical, economic, or social developments which will substantially alter current plans.

We create the outside users payload model from the bottom up in the sense that the data on discrete payloads are used to construct an overall demand model. The projections are based largely on transportation requirements of specific users of space transportation—for example, Intelsat—rather than on analyses of derived space transportation demand created by a given end market—for example, international telecommunications.

We have assembled two levels of activity, a high and a low model. These two models are not intended to represent absolute bounds on any program or mission category, but it is believed that there is a reasonable likelihood that the total activity will, on the average, fall within the indicated bounds. Historically, actual demand has been much closer to the low model than the high one. The two models thus define a range of potential demand which might be considered in making planning decisions.

Since a principal objective of our projections is to provide data on shuttle flight rates, we characterize all payloads in terms of equivalent shuttle flights.

For shuttle payloads, the equivalent portion of a shuttle flight is based upon the estimated load factor as defined in existing reimbursement policies Shuttle equivalent load factors for other launch vehicles are based upon determining the weight of a shuttle cargo, which could place the same spacecraft weight in geosynchronous transfer orbit as the launch vehicle in question.

This method of computing equivalent shuttle flights has an impact on the apparent demand. For example, implicit in this approach is the assumption that the shuttle is capable of carrying almost five SSUS-D class payloads. While it might be argued that this is an overstatement of shuttle capability, the approach is consistent with current shared flight reimbursement practices. To the extent that this approach overstates capacity, the mission models understate demands in terms of equivalent shuttle flights.

The next chart gives a breakdown of launch vehicle of the high model. The pie chart on the left is for payloads by number, while the pie chart on the right is by equivalent shuttle flights. Since we are primarily interested in the shuttle here, the right-hand figure is of importance.

I would like to make a few observations at this point. First, the shuttle has about 43 percent of the total demand locked up. Second, about 30 percent of the demand is potentially competitive between shuttle and Ariane, with shuttle likely getting about one-half of that segment. This would give the shuttle approximately 112 flights between now and 1998.

As a slight digression, I would like to point out there are a number of factors which a customer considers when choosing what transportation system to use. Among these are price, insurance, schedule availability, interface requirements, perceived reliability, and others.

The next chart shows the same information for the low model. In this case, the percent that the shuttle has locked up is only about 34, and the competitive proportion is also about 34 percent. The assessment of the most likely result indicates that the shuttle will get slightly more than half, or about 54 flights between now and 1998.

The number of flights per shuttle in the low model is about half that of the high, and the percentage captured is also decreased from approximately 60 in the high model to slightly over 50 in the low model.

I can explain why this happens by showing a comparison of the high and low models by mission category. Next chart, please. In this chart I have included only that portion of the models which will nominally go on shuttle. The left bar is for the high model and the right bar is for the low model. As I mentioned previously, the demand in the high model is about a factor of two larger than in the low model. Note that the communications market represents about one-half of the high model, but almost three-fourths of the low model.

The biggest swing area is that of materials processing which is over 42 equivalent shuttle flights in the high model, but only about 5 in the low model. Since material processing is primarily tied to the shuttle, it is this difference which creates the larger proportion of total demand being captured by the shuttle in the high model.

Let me comment on one other segment: low earth orbit observation satellites. This category is primarily weather satellites and any commercial, Landsat-type satellites. The total demand for these satellites is probably not going to change much, no matter if they are commercialized or not.

Now, let me make a few comments about the communications satellite market. This market has demonstrated that a profit can be made in space. Furthermore, that profit motive is very evident in future plans of the industry. One of the potential new uses of communications satellites is that of direct broadcast TV. The biggest questions about DBS are not technical but commercial; that is, can attractive programing be provided and can DBS compete with cable TV?

As I mentioned earlier, the demand for transportation for communications satellites is a derived demand, estimated to be between 40 and 55 equivalent shuttle flights between now and 1998. Other projections of this demand exist. When converting our projections to actual growth and communication capacity, the high and low models represent annual growth rates of 12.4 and 9.8 percent. These rates are consistent with other projections of communications demand.

I will not dwell on technology changes other than to say that changes such as fiber optics, increased satellite lifetimes, coding techniques, satellite switching networks, and others have an impact on the future market for communications satellite transportation.

Now, let me relate this material to the three areas I was asked to testify on. As I noted earlier, the shuttle flight rate demand is comprised of three components: NASA missions, DOD missions, and outside customers. My expertise is related only to this third component.

The high and low model outside customer projection in terms of equivalent shuttle flights, as defined by the reimbursement policy, are shown on the next chart. It has been our experience, based on annual projections made since 1975, that low model is the better estimator.

I should point out that due to manifesting considerations, the actual number of shuttle flights required to satisfy a given demand may exceed the number required based upon the reimbursement guidelines. In the early years of the program this occurs because of the shuttle's inability to deliver 65,000 pounds to orbit. In the later years, contingency situations, postponements, cancellations could cause a discrepancy between actual shuttle flights and the number of flights calculated based upon reimbursements from payloads which have flown.

Next, let me comment on the extended duration orbiter. By far the overwhelming portion of the cost associated with a shuttle flight is associated with the launch itself. For example, under NASA's second phase pricing policy, the price for launch and one day of on-orbit operation of a dedicated flight is roughly $81 million in 1984 dollars. By contrast, the price for an additional day of on-orbit operation is roughly $700,000. It follows that the total cost per day of on-orbit operation drops dramatically as the number of days on-orbit is increased. For example, extending the mission duration from 6 to 30 days would result in a theoretical reduction in per-day costs from $14 million to $3.4 million. Obviously, there are some additional costs associated with extended duration missions, but the general principle illustrated here holds true.

It is important to note that there must be a legitmate need for extended mission duration. This is not true in all cases, but the recent spacelab flight highlighted the intense time pressure of such missions. Providing additional time to perform experiments more carefully, to replicated experiments already performed, or to carry out more experiments on a single flight could result in dramatic increases in the science return from selected programs with only a very modest increase in the cost.

In looking at materials processing, it is important to recall that this is one of the potentially large future areas of commercial activity. One of the major problems in developing commercially viable MPS concepts is the long lead times from initial commitment to first sale of product. For the MDAC/Johnson and Johnson EOS, this is at least a decade, and the initial space experiments in that area were on Skylab 3 years previous to MDAC/J&J beginning their program.

The extended duration orbiter has the potential of benefiting a program such as the EOS in two ways during the R&D phase. The first is that more days on orbit will produce more products for ground testing, thus potentially reducing the number of flights in the test phase. The second is that longer on orbit times will allow for reconfiguration of the experiment or modification or repair based upon events in the first part of the mission. It must be cautioned that, since MPS test phase will most likely be doing endeavor flights or shared flights, the rationale for extending the mission duration should exist for the overall mission.

The Earth observation portion of the outside user payload model is not a significant portion. Most of these missions relate to supporting existing systems such as Landsat or Tiros. Whether these programs become commercialized or remain in the Government, the predominant mode of operation will be to launch replacement or follow-on satellites which are identical. However, when there is a need or desire to increase capabilities of such a system, a long duration—(20-day)—mission launched from Vandenberg would be an ideal testbed for instrument and system tests. Such a mission could be combined with delivery of other satellites.

The extended duration orbiter would be beneficial in certain technology demonstration missions, such as construction of large space structures or evaluation of new antenna or sensor designs. These missions would be NASA missions and very likely might be forerunners of future programs such as space station.

Based upon these types of missions, the outside customers could potentially benefit by extended duration missions in the late 1980's or early 1990's on portions of one to three flights per year based on the low model and one to three equivalent shuttle flights based on the high model. Because of the many uncertainties in the material processing area, it is difficult to refine this estimate.

Since my expertise is in only one segment of the total shuttle demand, I will not make an argument for or against the fifth orbiter based on demand. Many projections of this type have been made already.

Another consideration is that the shuttle is a critical national resource for the economy as well as for the national defense. While we hope that no major disaster will strike the shuttle program, any realistic assessment must recognize that there is a reasonable chance that there will be extended grounding of the shuttle fleet or, even worse, the loss of an orbiter.

Because the four-orbiter fleet will be working at or near its capacity, any prolonged grounding of the fleet will result in a backlog which could require years to fly off. The associated schedule slips could result in a significant shift from the shuttle to other launch vehicles, with a resultant increase in the cost per flight of the shut-

tle and potential balance of payment losses if customers shift to a foreign launch vehicle. It can be shown that some excess capacity in the system can drastically reduce the time required to fly off the backlog, thereby assisting in retaining customers, helping to control shuttle costs, and helping maintain a favorable balance of trade.

An even worse situation would arise if an orbiter were lost. Even the shuttle's severest critics would likely agree that a three-orbiter fleet is not adequate to meet defense, civil government, and commercial needs. One might thus look on a part of the cost of a fifth orbiter as an insurance policy. As one of my colleagues put it, "One of the most compelling arguments for a fifth orbiter is the fact that three orbiters aren't enough."

Mr. Chairman, this concludes my statement, and I will be pleased to try to answer any questions.

[The prepared statement of Mr. Fischer follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS ON
FEBRUARY 28, 1984

STATEMENT
OF
MR. NORMAN H. FISCHER
MANAGER, SPACE SYSTEMS SECTION
BATTELLE'S COLUMBUS LABORATORIES
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
HOUSE OF REPRESENTATIVES

Mr. Chairman and members of the Subcommittee, it is a pleasure to submit this testimony discussing Battelle's studies and views of Shuttle flight rate projections, the need for a fifth Shuttle orbiter, and requirements for an extended duration orbiter capability. First a few words of background on Battelle and its experience relative to the above topics. Battelle's Columbus Laboratories is a division of a worldwide 7,000 member research organization. The Columbus Laboratory has a staff of approximately 3,000 and is organized into departments as shown in Figure 1. The Space Systems Section is part of the Defense and Space Systems Department. The Space Systems Section has two decades of experience working for NASA Headquarters, with over ten years of that being related to Shuttle. The studies for NASA include payload projections, Shuttle operations, and Shuttle policy methodology. The payload projections for reimbursable customers have been done annually since 1975. This experience is the primary basis for my discussion. Major portions of this testimony are taken from Reference 1.

Before proceeding to some background material on the reimbursable users of Shuttle, a discussion of the total Shuttle demand is needed. There are three major components of Shuttle demand: NASA missions, DOD missions, and other (i.e., outside users). In determining flight rate projections, all three of these components need to be considered. NASA missions depend on a variety of factors including NASA's budget and future goals. The DOD demand is also a function of its goals, accomplishments, and budgets. It is not within Battelle's expertise to comment on any NASA or DOD flight rate which is within budget and satisfies organizational goals. The outside users are driven by external (to NASA/DOD) factors such as economics, other government agencies, and foreign government objectives. Battelle has projected such

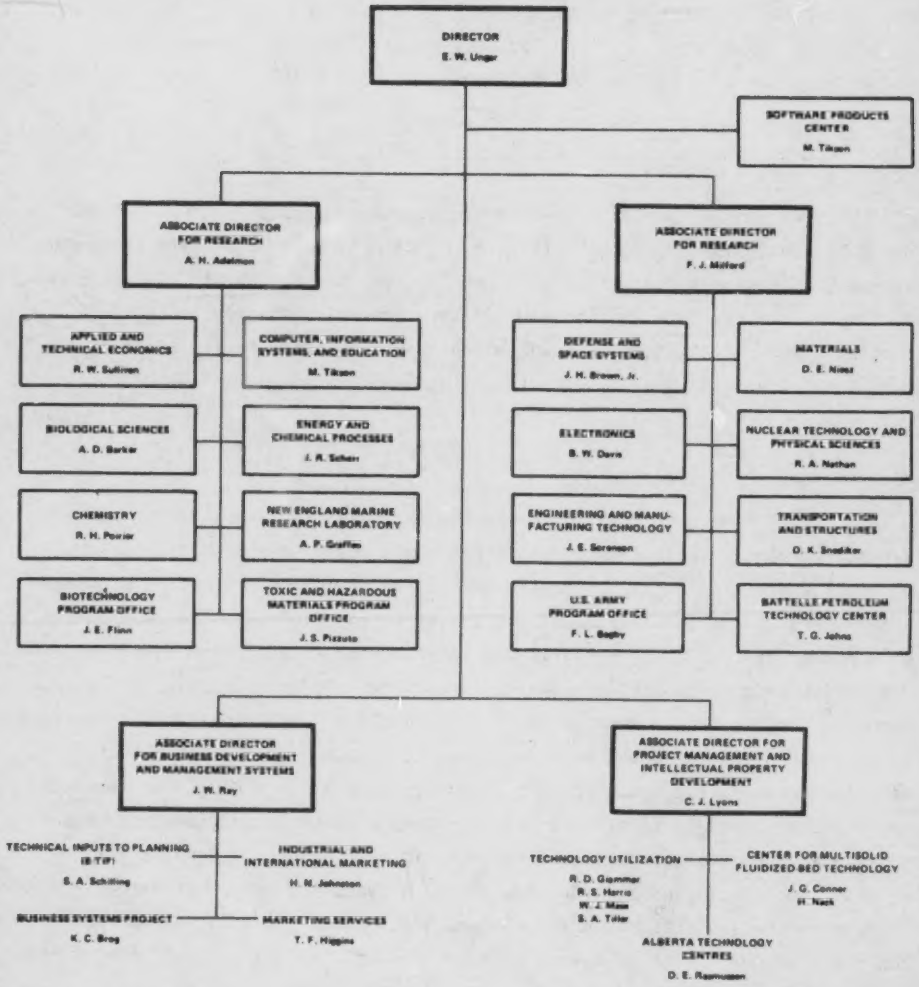

FIGURE 1. BATTELLE'S COLUMBUS DIVISION RESEARCH ORGANIZATION

activities for a number of years and will discuss this area. It is important to note that our projections are for free-world demand for transportation and an assessment is made as to how much of the total will be Shuttle customers.

Outside Users Payload Model Scope

All known non-NASA,non-DOD reimbursable payloads scheduled to be flown by non-Soviet-bloc countries* are included in this model with the exception of Spacelab payloads and Small Self-Contained Payloads. Certain DOD-sponsored or cosponsored payloads are included if they are reimbursable launches. A limited number of attached payloads which appear unlikely to fly as Spacelab payloads are not included.

Key Assumptions

The time during which this model was being prepared (Spring 1983) was one of considerable flux in key areas which could have significant impact on total space transportation demand and on the Shuttle's share of that demand. A presidential position statement was issued which encouraged the development of a commercial U.S. expendable launch vehicle (ELV) fleet. The likelihood and timing of a space station remained uncertain. Neither Shuttle nor Ariane had been trouble free. Reimbursement and operational policies for ETR retrievals and WTR operations were not well defined. Earth-based technologies such as fiber optics telecommunications showed promise of providing some services now being provided by satellites. Rather than attempt demand forecases based on such a wide range of potential futures, it was decided to prepare a more or less "business as usual" forecast on the grounds that any significant impacts on the subjects discussed above would be seen years in the future and could be dealt with in future models. Specific trends and potential threats are identified and discussed in a later section.

For purposes of this model, then, the following assumptions were made.

- Both Shuttle and Ariane are technologically successful and price competitive.

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* Payloads of the People's Republic of China are included in the model.

- U.S. commercial ELVs are not considered. Their entry into the market will likely have negligible effect on total market demand, but may alter the market share captured by each vehicle.
- Potential space station impacts are not considered. These impacts can be defined in more detail once a firm space station concept and timetable are established.
- There will be no revolutionary technical, economic, or social developments which will substantially alter current plans.

Nature of the Forecasts

The Outside Users Payload Model is created from the bottom up in the sense that data on discrete payloads are used to construct an overall demand model. The projections are based largely on information about specific transportation requirements of specific users of space transportation (e.g., INTELSAT) rather than on analyses of derived space transportation demand created by a given end-market demand (e.g., international telecommunications).

In general, the model is based only on demand and is not assumed to be capacity limited. However, in the near term, user plans may be based on projected available capacity and may to some extent be capacity limited.

Because both user plans and NASA needs are defined in terms of discrete payloads rather than average rates, this model also is expressed in terms of discrete payloads. In the near term, the data on the payloads themselves should be reasonably accurate. Near-term launch forecasts are the best available, but there has been a considerable history of slippage in all launch schedules. Substantially more latitude should be given to the longer term forecasts. These might best be interpreted as indications of probable activity levels in approximate time frames. At a minimum, it should not be inferred that the level of precision expressed in some of the tables is an indication of the accuracy of the forecasts.

While the models draw heavily on data on specific user plans, some adjustments have been made. These adjustments reflect the judgments on such matters as the likelihood of achieving a stated schedule, the impact of total market demands on the viability of all the announced candidates to provide

a given service, etc. In addition, adjustments in long-range demand are included in the form of follow-on and "market forecast" payloads. The follow-ons consist of payloads which may be used to replace and/or expand an existing service. Market forecasts are hypothetical payloads inserted in recognition of the fact that there will be additional long-term demand which has not been identified.

"High" and "Low" Model Concepts

Two levels of activity, a "High" and a "Low" model have been assembled. These two models are not intended to represent absolute bounds on any program or mission category, but it is believed that there is a reasonable likelihood that total activity will, on the average, fall within the indicated bounds. (Historically, actual demand has been much closer to the Low model than the High one.) The two models thus define a range of potential demand which might be considered in making planning decisions.

Inherent in the High model are the assumptions of sustained growth in established demand and the early success of planned new activities; e.g., direct broadcasting and materials processing. In general, this model is based on announced plans, with additional market forecast payloads included in later years. Few program delays are assumed.

A general reduction of the level of activity is assumed in the Low model. This could result from a variety of causes. Among them are slower growth in total demand, budgetary problems in government programs, technological improvements which allow demand to be met with smaller payloads or payloads with longer life, capture of a part of the total demand by a competing terrestrial technology, and unanticipated schedule slips.

Estimation of Equivalent Shuttle Flights

Since a principal objective of this document is to provide data on Shuttle flight rates, an attempt is made to characterize all payloads in terms of equivalent Shuttle flights. The payloads considered vary widely in size, weight, shape, destination, and are scheduled to be launched on

a number of different launch vehicles, so the conversion is not necessarily a straightforward one.

For Shuttle payloads, the equivalent portion of a Shuttle flight is based on the estimated load factor as defined in existing reimbursement policies. Where both the length and weight of the payloads are known, both length and weight load factors are computed and the larger is used. Computation of the weight load factor is based on advertised Shuttle capability to the intended orbit (e.g., 65,000 lbs to 28.5°/160 nm, 32,000 lbs to 98°/160 nm). For payloads not yet well defined, estimated Shuttle payload weight is used as the basis for computing load factor on the assumption that these payloads likely will be Shuttle-optimized such that length and weight load factors are essentially identical.

The construction of the Shuttle equivalent load factors for other launch vehicles is based on determining the weight of a Shuttle cargo which could place the same spacecraft weight in geosynchronous transfer orbit as the launch vehicle in question. For each vehicle, the maximum capability of the launcher is used as opposed to the weight of a specific payload. The resulting load factors based upon these assumptions are shown in Table 1.

Once the equivalent Shuttle load factor is computed for each payload, this is converted into equivalent Shuttle flights in the same way that the Shuttle charge factor is computed from the load factor. If the payload's load factor is 0.75 or less, the Shuttle flight equivalent is computed by dividing the load factor by 0.75. If the load factor is greater than 0.75, the Shuttle flight equivalent is set to 1.0.

The method of computing equivalent Shuttle flights has a significant impact on the apparent demand. For example, implicit in this approach is the assumption that the Shuttle is capable of carrying almost five SSUS-D class payloads. While it might be argued that this is an overstatement of Shuttle capability, the approach is consistent with current shared-flight reimbursement practices. To the extent that this approach overstates capacity, the mission models understate demand in terms of equivalent Shuttle flights.

TABLE 1. EQUIVALENT SHUTTLE LOAD FACTORS FOR VARIOUS LAUNCH VEHICLES[a]

Launch Vehicle	Payload to Geosynchronous Transfer, lbs	Equivalent Shuttle Load Factor
Delta 3910/PAM	2450	.13
Delta 3920/PAM	2800	.14
Atlas Centaur	4520	.23
Atlas Centaur (Improved)	5200	.27
Scout(b)	--	.02
M-3S(b)	--	.02
N-I	570	.03
N-II	1500	.08
H-I	2370	.12
Ariane I	3700	.20
Ariane II	4400	.25
Ariane III	5450	.30
Ariane IV	9500	.53
	Dual Launch	
Ariane I	1690	.10
Ariane II	2040	.12
Ariane III	2500	.15
Ariane IV	3500-6000	.18-.35

(a) See text for assumptions.
(b) Based on equivalent weight to LEO.

Mission Categories

The Outside Users Payload Model divides the users into the following categories:

(1) International Communications
(2) U.S. Domestic Communications
(3) Foreign Regional Communications
(4) U.S. Geostationary Earth Observations
(5) Foreign Geostationary Earth Observations
(6) U. S. Low Earth Obse vations
(7) Foreign Low Earth Observations
(8) Navigation Aids
(9) Foreign Planetary
(10) Scientific/Technical Development
(11) Materials Test/Processing
(12) Multiservice Spacecraft Vehicles

These categories are primarily self-explanatory; detailed discussions are contained in Reference 1. Table 2 presents the equivalent Shuttle flights total demand by mission category for the High and Low models. It must be recognized that the Shuttle will not capture all the demand. Ariane, "N", U.S. ELVs, etc., will all capture portions of the demand. Based on conditions which existed in June 83, a projected market split by vehicle for the High and Low models was developed and is shown in Figures 2 and 3. Since the interest here is in Shuttle flight rate projections, the nominal STS demand by market segment is shown in Table 3.

Figure 4 summarizes the STS demand for the High and Low model by mission category. Several important facts can be seen from this figure:

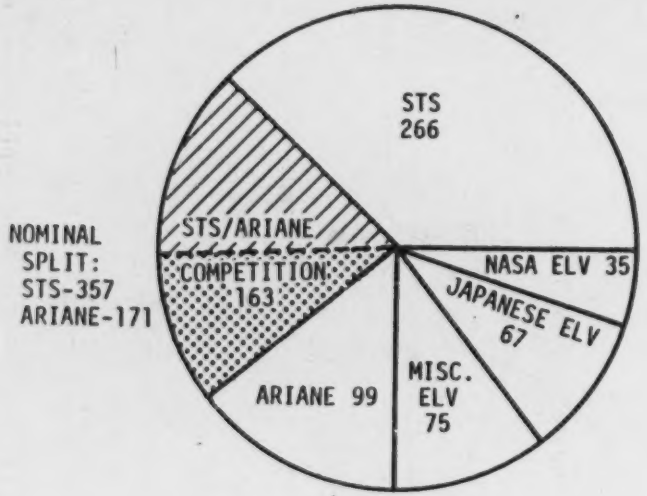
(1) The total demand varies between the High and Low models by a factor of 2.
(2) The communications market represents approximately one-half of the High model and almost three-fourths of the Low model.
(3) Materials processing (MPS) represents about three-eights (38 percent) of the High model but only about one-tenth of the Low model.

TABLE 2. EQUIVALENT SHUTTLE DEMAND BY MISSION CATEGORY[1,2]

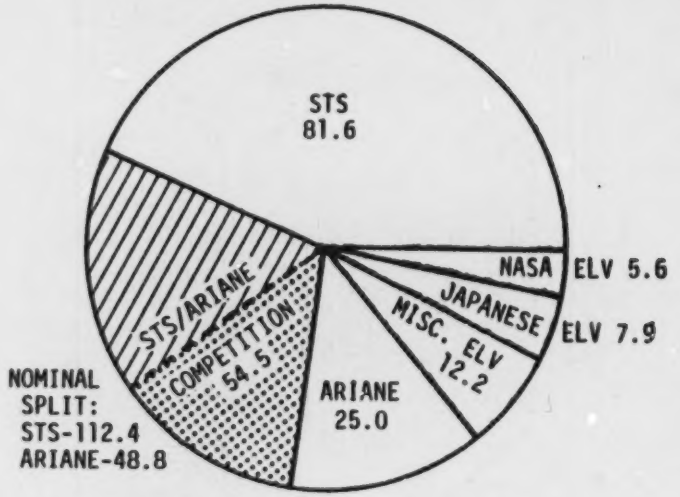
	MODEL	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	TOTAL
INTERNATIONAL COMM	H	1.20	1.25	.72	1.41	2.12	1.41	1.41	2.83	2.83	2.12	1.41	1.41	1.41	2.12	2.12	2.12	28.00
	L	.57	1.25	1.08	1.07	1.41	2.12	1.41	2.00	2.79	1.37	.69	1.37	.71	1.41	1.41	1.41	22.15
U.S. DOMESTIC COMM	H	1.91	3.81	2.80	2.00	2.53	1.75	1.45	1.29	.73	1.29	3.63	3.56	2.53	1.92	2.91	2.57	36.72
	L	1.91	2.44	3.61	1.44	1.07	.91	2.01	1.01	.72	1.28	3.72	3.00	2.01	1.00	.36	.72	28.31
FOREIGN REC COMM	H	1.36	1.71	2.21	2.47	2.31	1.24	2.55	1.84	2.23	3.09	3.15	1.96	3.23	3.99	2.27	4.24	39.93
	L	1.36	1.32	1.44	1.50	2.17	.77	1.03	3.00	1.85	.85	1.72	3.11	.67	.40	1.68	1.91	23.07
U.S. GEO OSS	H	.17	.00	.00	.37	.00	.00	.19	.19	.19	.00	.37	.00	.00	.19	.19	.19	2.04
	L	.17	.00	.00	.37	.00	.00	.19	.19	.19	.00	.37	.00	.00	.00	.00	.00	1.48
FOREIGN GEO OSS	H	.00	.11	.00	.00	.36	.40	.11	.49	.00	.36	.29	.40	.85	.36	.40	.49	4.63
	L	.00	.11	.00	.00	.36	.40	.11	.20	.00	.00	.00	.52	.56	.20	.36	.00	2.81
U.S. LEO OSS	H	.13	.00	.07	.07	.75	.07	.75	.20	.95	.20	.95	.33	1.21	.53	1.21	.73	8.15
	L	.13	.00	.07	.07	.75	.07	.75	.07	.20	.81	.00	1.15	.00	.00	.95	.40	5.40
FOREIGN LEO OSS	H	.00	.03	.20	.27	.43	.77	.44	1.17	.99	.48	.77	.80	.95	1.29	1.15	.88	10.71
	L	.00	.00	.16	.27	.23	.24	.60	.67	.52	.87	.40	.41	.53	.69	.33	.27	6.29
NAVIGATION AIDS	H	.04	.04	.03	.00	.00	.05	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.24
	L	.00	.04	.00	.00	.04	.00	.00	.00	.00	.03	.05	.00	.00	.03	.00	.00	.19
FOREIGN PLANETARY	H	.00	.04	.37	1.00	.00	.33	.00	.16	.00	.33	.16	.00	.16	.33	.40	.00	3.29
	L	.00	.04	.37	1.00	.00	.00	.00	.16	.00	.00	.00	.00	.16	.00	.40	.00	2.13
SCI/TECHNICAL DEV	H	.56	.16	.71	.45	.67	.45	.51	.36	.40	.43	.64	.33	.40	.43	.40	.52	7.71
	L	.52	.20	.51	.41	.63	.40	.20	.23	.40	.20	.31	.13	.43	.16	.17	.33	5.43
MATERIALS PROCESS	H	.00	.00	.00	.27	.77	.53	1.96	2.91	2.80	3.69	4.91	4.80	4.80	5.17	4.93	4.93	42.48
	L	.00	.00	.00	.59	.96	.27	.40	.13	.27	.27	.51	.27	.40	.27	.53	.27	5.12
MULTISERVICE	H	.21	.00	.00	.19	.04	.00	.63	.19	.00	.44	.00	.00	.44	.00	.63	.19	2.95
	L	.21	.00	.00	.19	.04	.00	.19	.19	.44	.00	.00	.00	.44	.00	.19	.00	1.88
TOTAL	H	5.59	7.24	7.20	8.56	9.97	7.21	10.01	11.63	11.31	12.44	16.20	13.69	16.09	16.33	16.63	16.87	186.04
	L	4.88	5.40	7.44	7.19	7.65	5.39	6.88	6.92	7.37	5.79	7.75	9.04	6.71	4.14	6.39	5.12	104.25

[1] Includes all payloads in this model.

[2] Assumes 75% Shuttle load factor.



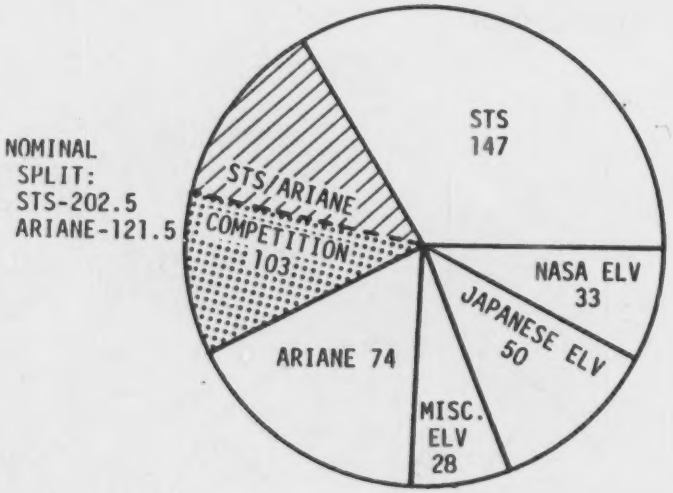
705 PAYLOADS



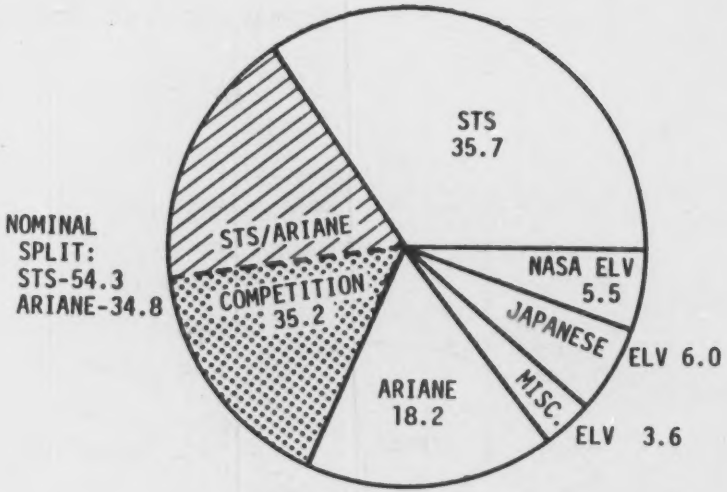
187 EQUIVALENT SHUTTLE FLIGHTS[1]

1. ASSUMES 75% average Shuttle load factor.

FIGURE 2. HIGH MODEL MARKET SHARE BY LAUNCH VEHICLE



435 PAYLOADS



104 EQUIVALENT SHUTTLE FLIGHTS[1]

1. Assumes 75% average Shuttle load factor.

FIGURE 3. LOW MODEL MARKET SHARE BY LAUNCH VEHICLE.

TABLE 3. NOMINAL STS DEMAND BY MISSION CATEGORY--EQUIVALENT SHUTTLE FLIGHTS

	MODEL	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	TOTAL
INTERNATIONAL COMM																		
	H	.00	.00	.00	.71	1.24	.35	.71	1.24	1.77	1.24	1.06	1.06	1.06	1.59	1.59	1.59	18.19
	L	.00	.00	.00	.53	.71	.53	.35	1.06	1.22	.86	.33	.86	.53	1.06	1.06	1.06	10.15
U.S. DOMESTIC COMM																		
	H	1.00	3.08	2.25	1.17	1.61	1.33	1.36	1.11	.64	1.06	3.45	3.28	2.31	1.61	2.19	2.13	29.61
	L	1.00	2.08	2.88	.91	.61	.72	1.36	.78	.68	1.01	3.50	2.90	2.59	.86	.31	.69	22.87
FOREIGN REG COMM																		
	H	.52	.55	.92	.15	.69	.52	.69	.38	.65	1.12	.71	.42	1.00	.64	.43	.91	10.30
	L	.52	.36	.55	.29	.46	.19	.67	.38	.70	.19	.31	.43	.05	.10	.37	.40	5.95
U.S. GEO OBS																		
	H	.00	.00	.00	.00	.00	.00	.19	.19	.19	.00	.37	.00	.00	.19	.19	.19	1.49
	L	.00	.00	.00	.00	.00	.00	.19	.19	.19	.00	.37	.00	.00	.00	.00	.00	.93
FOREIGN GEO OBS																		
	H	.00	.00	.00	.00	.00	.05	.00	.00	.00	.05	.00	.05	.00	.05	.00	.05	.25
	L	.00	.00	.00	.00	.00	.05	.00	.00	.00	.00	.00	.00	.05	.00	.00	.00	.10
U.S. LEO OBS																		
	H	.00	.00	.00	.00	.75	.07	.75	.07	.95	.07	.95	.20	.95	.40	.95	.80	6.68
	L	.00	.00	.00	.00	.75	.07	.75	.07	.20	.81	.00	1.15	.00	.00	.95	.40	5.13
FOREIGN LEO OBS																		
	H	.00	.00	.00	.00	.00	.09	.00	.55	.00	.00	.09	.09	.47	.09	.09	.09	1.54
	L	.00	.00	.00	.00	.00	.00	.00	.00	.00	.55	.00	.00	.00	.09	.00	.00	.64
NAVIGATION AIDS																		
	H	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	L	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
FOREIGN PLANETARY																		
	H	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00
	L	.00	.00	.00	1.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	1.00
SCI/TECHNICAL DEV																		
	H	.09	.00	.00	.00	.23	.09	.14	.09	.14	.03	.05	.03	.00	.03	.08	.03	1.10
	L	.09	.00	.00	.00	.23	.00	.09	.00	.14	.00	.03	.00	.00	.00	.03	.00	.69
MATERIALS PROCESS																		
	H	.00	.00	.00	.27	.77	.83	1.96	2.91	2.00	3.69	4.91	4.80	4.80	3.17	4.93	4.93	43.48
	L	.00	.00	.00	.59	.96	.27	.40	.13	.27	.27	.51	.27	.40	.27	.53	.37	5.12
MULTISERVICE																		
	H	.21	.00	.00	.14	.04	.00	.63	.14	.00	.44	.00	.00	.44	.00	.58	.14	2.76
	L	.21	.00	.00	.14	.04	.00	.19	.14	.44	.00	.00	.00	.44	.00	.14	.00	1.74
TOTAL																		
	H	1.83	3.63	3.17	3.44	5.33	3.03	6.42	6.67	7.13	7.69	11.58	9.92	11.10	9.78	11.02	10.66	112.41
	L	1.83	2.44	3.43	3.45	3.76	1.87	3.99	2.72	3.83	3.70	5.06	5.60	4.13	2.18	3.19	2.42	54.32

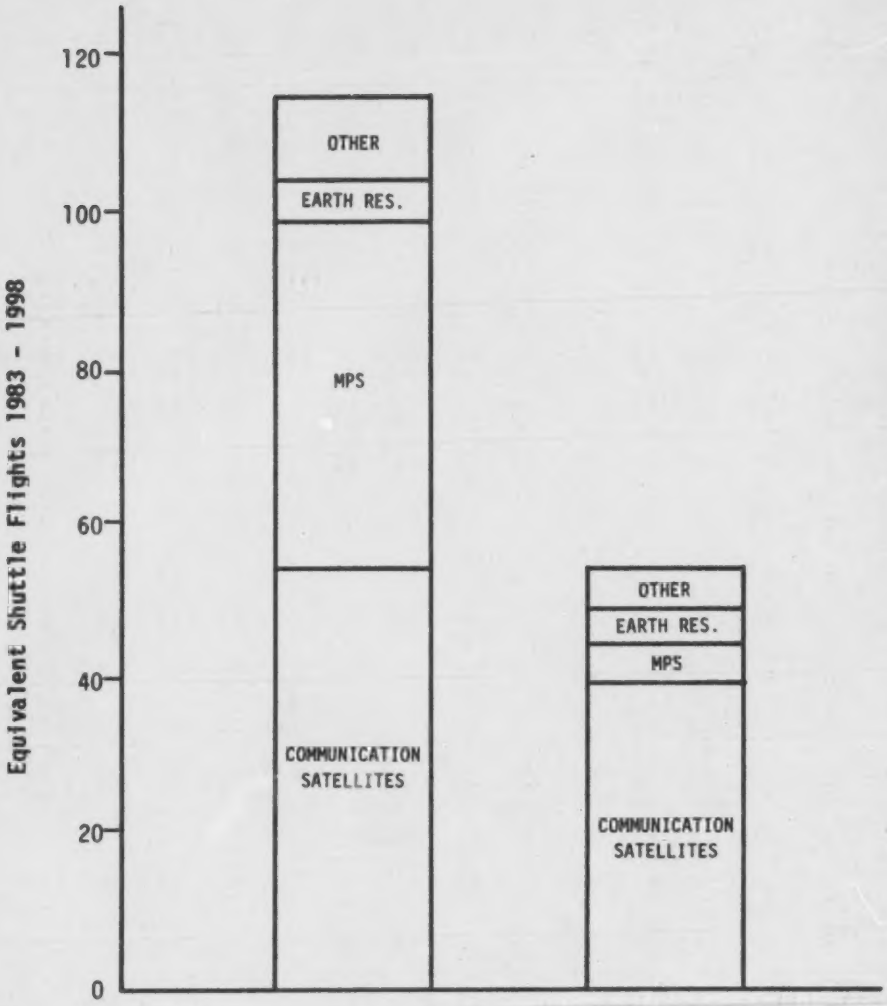


FIGURE 4. STS DEMAND BY MISSION TYPE

(4) The only other significant category is weather satellites (NOAA) which represents 5 to 10 percent of the models, but the total demand is nearly the same in High and Low models.

Since there are some significant variations in the projected demand of the communications and materials processing markets, an analysis of these areas is warranted.

Communications Satellites

The basic concept of the communications satellite as an economically successful venture was established by Telstar. It must be recognized that the transportation demand for communications satellites is a derived demand. The actual demand is for telephone service, data transfer, and broadcasting. The total demand as estimated in the High and Low models as shown in Figure varies between approximately 40 and 55 Equivalent Shuttle Flights. This uncertainty is caused by both the uncertainty in the growth of communications demand and in the technology changes coming along which can impact the total weight of the spacecraft going into orbit.

For both the High and Low models, the actual communications capacity on orbit, as represented by equivalent transponders, is growing significantly,at rates of 12.4 and 9.8 percent per year respectively. One of the largest areas of uncertainty in demand is the direct broadcast satellite (DBS) area. The biggest questions about DBS are not technical but commercial, e.g., can attractive programming be provided and can DBS compete with cable TV.

Fiber Optics

Fiber optics technology is evolving rapidly. A number of intracity trunks exist and a major link between Washington, D.C. and New York is operational--and will soon be extended to Boston. The Bell system reportedly has contracts or requests for proposals out on some 1100 miles of line. MCI Corporation plans an initial line running the length of the eastern seaboard with branches running to Texas and Chicago. The first transatlantic fiber optic cable is planned to go into service in 1988, and the Japanese are considering laying a fiber optic cable from Japan to Hawaii.

Among the advantages of fiber optic links are freedom from interference, greater security, and elimination of the time lag inherent in satellite communications. They also provide a form of backup system in the even of failure or destruction of satellite links. The relative economic merits of satellite versus fiber optic communications are yet to be determined, largely because of the rapid rate of change of both technologies.

Because of the great investments in physical plants (both existing and future), any transition from satellite to fiber optics communications will take place over fairly long time periods. Such a transition will normally enter this mission model in the form of reduced demand forecasts on the part of satellite builders and operators. In general, it is expected that any demand reduction will be in the area of high density point-to-point transmission. Specific areas of potential impact include international communications and those intranational systems which lend themselves to installation of terrestrial links. At present, the majority of transponders serving U.S. domestic markets provide TV broadcast service and seem less susceptible to fiber optics competition in the near term than do the high-volume point-to-point carriers.

Improved Performance

In addition to fiber optics technology, there continue to be other relevant advancements in the communications field. Broadly speaking, these might be classified into advances which have a significant impact on communications in general and those which are satellite-communications specific. Among the former are various techniques used to increase the capacity of any channel, e.g., techniques for signal compression. Such techniques permit the meeting of increased demand with fewer channels, essentially regardless of the transmission medium. Satellite-unique improvements in such areas as solar cells, batteries, electronic component size, reliability, and satellite lifetime help improve the competitiveness of satellites by reducing cost per unit of channel capacity. Both general improvements and those which are satellite-unqiue tend to reduce the demand for transportation, given a fixed communications demand. Satellite-unique improvements do, however, tend to make satellites more competitive with other media. Table 4 is a

graphic illustration of the increase in satellite capacity with time. It can be seen that the unit capacity, that is, the number of circuit-years of service per pound of spacecraft weight, has increased 20-fold in 20 years, and will essentially double between Intelsat V-A and Intelsat IV.

TABLE 4. GROWTH OF INTELSAT SATELLITE PERFORMANCE

Year	Series	Design Life (yr)	Circuits	Weight (lbs)	Unit Capacity (ckt-yrs/lb)
1965	I	1.5	240	85	4.2
1967	II	3	240	190	3.8
1968-70	III	5	1,500	334	22.4
1971-75	IV	7	4,000	1,610	17.4
1975-78	IV-A	7	6,480	1,898	23.9
1979-84	V	7	12,480	2,231	39.2
1984-85	V-A	7	15,000	2,250	46.6
1986-91	VI	10	34,000	3,918	86.8

DBS Power Levels

In the field of direct broadcast TV systems (DBS), there is an ongoing controversy over the relative merits of high-power and low-power systems. Recent developments include a low-power operational system in the U.S. Should low-power technology become the standard, this would tend to reduce the demand for transportation in that operators could use smaller satellites, spread beams over a larger area, or lease channels on existing satellites.

Orbital Arc Allocation

In April 1983, the FCC significantly modified the orbital arc spacing requirements for satellites. A shift to 2-degree spacing for K_u-band satellites will take place almost immediately while reduced spacing for C-band satellites will be implemented over several years to accommodate satellites either already on orbit or committed for launch.

The full orbital arc of Region 2 is roughly 120 degrees in length, and the available spectrum is 500 MHz in each of the C and K_u bands. With no frequency reuse, about twelve 36-MHz transponders can be operated in the available 500 MHz of each band. These capacities can be effectively doubled by full reuse of the available spectrum by using orthogonal polarization. This is already being done with a number of recent and projected satellites. The capacity of each band then would theoretically be 1440 transponders. From a practical point of view, it has been suggested that only 88 degrees of arc in Region 2 (55°W to 143°W) would be used extensively because of the geography of the region. Applying this constraint to the figures given above yields practical capacities of about 1050 transponders in each band. It should be pointed out that capacity could be increased further by:

(1) Use of spot and disjoint areas beams (already being done by some satellites)

(2) Use of advanced communications techniques to permit more efficient utilization of the available spectrum

(3) Allocation of additional spectrum within the bands.

Platforms and Clusters

The geosynchronous arc has the potential of becoming crowded by the end of this century. Because of this crowding and the potential economies of scale afforded by geosynchronous platforms, some advocate platforms as the methods of doing business in the future. Others suggest that cluster concepts offer the same advantages as platforms, but without some of the institutional problems.

The transition from current methods of operation in the geosynchronous orbit to these new modes requires the solution of a variety of problems including

organization arrangements, legal aspects, new insurance concepts, transitional scheduling from current modes, and technical issues. In considering these issues in the perspective of this model, it is difficult to forecast when or if a transition to a platform or clusters mode would take place. The earliest envisioned transition to multi-institution platforms would be the early to mid-1990s, a time when space station could become operational. The main objective of this model is to estimate future traffic demand. The net change in traffic demand, if any, caused by a transition to platforms is both difficult to assess and distant in time. For these reasons, this model does not consider specific impacts or platform/cluster technology.

Materials Test and Processing

Materials processing has been considered as the major new area for the commercial use of space since Skylab. In the 1970s there were hundreds of ideas of potential things to make in space. However, from these many ideas there are only a small number which are considered as potentially commercial activities. Nevertheless, the materials processing mission category has the potential of becoming one of the major segments of the overall model. However, there are still a great number of uncertainties regarding the commercial viability of materials processing in space. Consequently, there is a large difference between the High and Low models.

The NASA Joint Endeavor Agreement (JEA) program will likely be the beginning of the potential commercial operations. The initial JEA was established with McDonnell Douglas Astronautics Company and Johnson and Johnson (MDAC/JJ) for their Electrophoresis Operations in Space (EOS) program. The MDAC/JJ EOS program began in 1976 and had its first flights in the Shuttle mid-deck in 1982. Additional JEA flights are scheduled in the 1983-1986 time period. These JEA flights, being non-reimbursable, are not shown in the model. In the High model, the EOS program is shown as beginning commercial operations in the late 1980s and growing to full-scale operation in the 1990s. In the Low model, however, the EOS program is shown as being tried in the 1980s and not being continued. A number of factors could cause this. They include technical problems, economic viability, and development of a less

expensive ground-based system. In both the High and Low models, it is assumed that a mix of shared and dedicated flights will be used in conjunction with the use of Fairchild Leasecraft hardware.

Although there are a large number of other products/processes which have been considered for materials processing in space, only a few have been identified as having a chance at becoming commercial ventures. These are production of Gallium Arsenide chips and Mercury Cadmium Telluride detectors, an isoelectric focusing separation technique which would complement EOS, and a small-scale research program in metals/ceramics which would be used to better understand ground processes. In the High model, all four of these possibilities are included, while in the Low model only one is shown as being successful.

In the foreign area, ESA's EURECA mission is included in both models, as well as some generic materials processing, which could be an outgrowth of German, French, or Japanese programs.

One of the major problems with commercial ventures in the materials processing area is the long lead times involved. The MDAC/JJ EOS program will have at least ten years from beginning to sale of first commercial product. This is probably longer than what could happen in other cases due to the requirement for FDA approval of new drugs. But still, these long times before receiving any return on investment are a major concern of venture capitalists and commercial developers.

Other factors which impact materials processing in space are changes in technology. During the past year, McDonnell-Douglas/Johnson and Johnson demonstrated considerable success in electrophoretic orbital separation (EOS). Commercial firms showed increased interest in the preparation of semiconductors in a zero-g environment. It is significant that all the products initially being considered can be made using terrestrial processes. Space processing will be attractive for these products only if it yields an economic advantage over terrestrial processes. The competition of terrestrial processes might take two forms. Optimization of a terrestrial process (e.g., electrophoretic separation) prior to space operations could substantially improve the competitiveness of the ground-based process. Alternative processes also might be developed. For example, great strides are being made in the production of biological materials through genetic engineering. To the extent that the same products

might be produced by such techniques, there exists a threat to space-processed products.

The evolution of orbital factories, typified by the Fairchild Leasecraft concept, may contribute to the economic viability of space processing by reducing space transportation costs--hence reducing STS revenues for a given amount of demand. Market price elasticity for specific products may interact with transportation price in setting the equilibrium demand for MPS space transportation.

Flight Rate Projections

As it has been noted earlier the Shuttle flight rate demand is comprised of three components: NASA missions, DoD missions and outside customers. Battelle's experience and expertise is related only to this third component. The High and Low Model outside customer projections in terms of equivalent Shuttle flights, as defined by the reimbursement policy, are shown in Figure 5. It has been Battelle's experience, based on annual projections made since 1975, that the Low model is the better estimator. It should be pointed out that due to manifesting considerations, the actual number of Shuttle flights required to satisfy a given demand may exceed the number required based upon the reimbursement guideline. In the early years of the program this occurs because of the Shuttle's inability to deliver 65,000 lbs to orbit. In the latter years contingency situations, postponements and cancellations will likely cause a discrepancy between actual Shuttle flights and the number of flights calculated based on reimbursements from payloads which have flown.

Extended Duration Orbiter

By far the overwhelming portion of the cost associated with a Shuttle flight is associated with the launch itself. For example, under NASA's second phase pricing policy, the price for launch and one day of on-orbit operation of a dedicated flight is roughly $81 million in 1984 dollars. By contrast, the price for an additional day of on-orbit operation is roughly $700,000. It follows that the total cost per day of on orbit operation drops dramatically

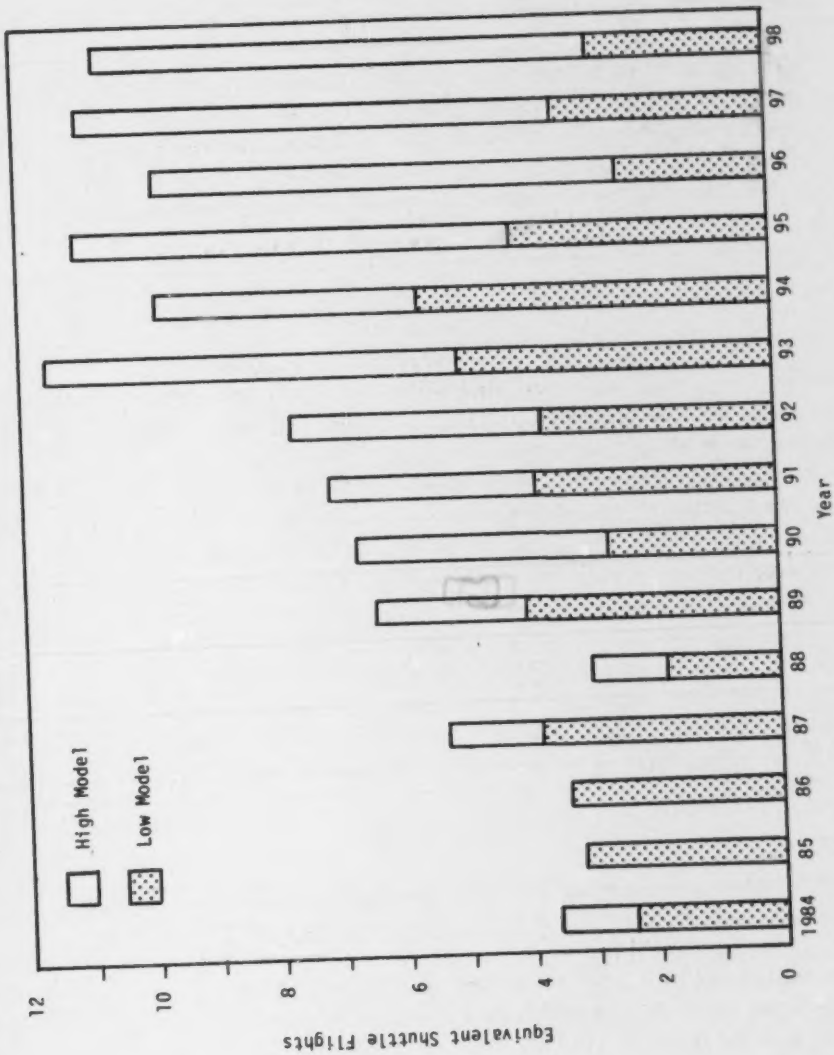


FIGURE 5. STS DEMAND 1984 - 1998

as the number of days on-orbit is increased. For example, extending the mission duration from 6 days to 30 days would result in a theoretical reduction in per-day costs from $14 million to $3.4 million. Obviously there are some additional costs associated with extended-duration missions, but the general principle illustrated here holds true.

It is important to note that there must be a legitimate need for extended mission duration. This is not true in all cases, but the recent Spacelab flight highlighted the intense time pressure on such missions. Providing additional time to perform experiments more carefully, to replicate experiments already performed, or to carry out more experiments on a single flight could result in dramatic increases in the science return from selected programs with only a very modest increase in cost.

In looking at materials processing it is important to recall (see Figure 4) that this is one of the potentially large future areas of commercial activity. One of the major problems in developing commercially viable MPS concepts is the long times required from initial commitment to first sale of product. As noted, for MDAC/JJ EOS this is at least a decade, and the initial space experiments in that area were on Skylab three years previous to MDAC/JJ beginning their program. The extended duration orbiter has the potential of benefiting a program such as the EOS in two ways during the R&D phase. The first is that more days on orbit will produce more products for testing, thus potentially reducing the number of flights in the test phase. The second is that longer on-orbit times will allow for reconfiguration of the experiment or modification/repair based upon events in the first part of the mission. It must be cautioned that, since the MPS test phase will most likely be JEA flights or shared flights, the rationale for extending the mission duration should exist for the overall mission.

The Earth observations portion of the Outside Users Payload Model is not a significant portion. Most of these missions relate to supporting existing systems such as Landsat or TIROS. Whether these programs become commercialized or remain in the government, the predominant mode of operation will be to launch replacement/follow-on satellites which are identical. However, when there is a need or desire to increase capabilities of a systems, a long duration (20 day) mission launched from Vandenberg would be an ideal test

bed for instrument and system tests. Such a mission could be combined with the delivery of another satellite(s).

The extended duration orbiter would be beneficial in certain technology demonstration missions, such as construction of large space structures or evaluation of new antenna or sensor designs. These missions could be NASA missions and very likely might be forerunners of future programs such as Space Station.

Based upon these types of missions, the outside customers could potentially benefit by extended duration missions in the late 1980s or early 1990 on portions of one to three flights per year based on the "Low" model and on one to three equivalent Shuttle flights based on the "High" model. Because of the many uncertainties in the material processing area it is difficult to refine this estimate.

Fifth Orbiter

Since Battelle's expertise is in only one segment of total Shuttle demand, an argument for or against the fifth orbiter will not be made on demand. Many projections of this type have been made already.

Another consideration is that the Shuttle is a critical national resource for the economy as well as for national defense. While we all hope that no major disaster will strike the Shuttle program, any realistic assessment must recognize that there is a reasonable chance that there will be an extended grounding of the Shuttle fleet or, even worse, the loss of an orbiter.

Because the four-orbiter fleet is working at or near its capacity, any prolonged grounding of the fleet will result in a backlog which could require years to fly off. The associated schedule slips could result in a significant shift from the Shuttle to other launch vehicles, with a resultant increase in the cost per flight of the Shuttle and potential balance of payment losses if customers shift to a foreign launch vehicle. It can be shown that some excess capacity in the system can drastically reduce the time required to fly off the backlog, thereby assisting in retaining customers, helping to control Shuttle costs, and helping maintain a favorable balance of trade.

An even worse situation would arise if an orbiter were lost. Even the Shuttle's severest critics would likely agree that a three-orbiter fleet

is not adequate to meet defense, civil government, and commercial needs. One might thus look on a part of the cost of a fifth orbiter as an insurance policy. As one colleague put it, "One of the most compelling arguments for a fifth orbiter is the fact that three orbiters aren't enough."

Reference 1. 1983 Outside Users Payload Model, to NASA from Battelle's Columbus Laboratories.

NORMAN H. FISCHER

Section Manager
Space Systems Section

Education

B.S., Mathematics, Case Institute of Technology
M.S., Mathematics, The Ohio State University

Qualifications

Mr. Fischer has been working in the space systems area since joining Battelle in 1966. He is manager of Battelle's Space Systems ~~and Applications~~ Section which is comprised of about 30 people and does approximately $2 million of business annually. He has been project manager on a broad range of studies ranging from small studies on specific technical problems to large multidisciplinary, multiyear projects. His diverse technical background includes work in the following areas: payload market projections, future propulsion requirements, future systems operational requirements, trajectory optimization/orbital mechanics, and guidance analyses.

Relevant Experience at Battelle

Project Manager for NASA Launch Vehicle Project. Managed multidisciplinary project sponsored by NASA Headquarters and funded at over $1 million per year for four years. The major project areas were:

- Expendable Launch Vehicle Planning
- Non-NASA/non-DoD payload forecasting
- STS policy and customer services
- Shuttle mission planning tools (IGOS).

Non-NASA/Non-DoD Payload Forecasting. Produced 1981 and 1982 updates of the forecast of space use by organizations other than NASA, DoD, and Soviet Union. Expanded forecast to indicate market shares (reimbursable revenues) which could be captured by STS and Ariane.

Delta Launch Vehicle Guidance Study. Managed study on the Delta Inertial Guidance Systems (1975-1983). Assessed DIGS and DRIMS (Delta Redundant Inertial Measurement System) for system performance, software problems and sensor failure modes.

Trajectory Mechanics Studies. Developed launch vehicle trajectory optimization program. Developed trajectory mechanics procedures to support work on STS ETR retrieval and VAFB operational shared flight policies. Contributed to work on development of program to analyze Shuttle operations and time lines.

NORMAN H. FISCHER (Continued)

Multimission Modular Space Propulsion. Managed study to assess propulsion requirements for the MMS.

Professional Recognition and Affiliations

Member of AIAA and Space Systems Technical Committee of AIAA. Member of Sigma Xi.

Selected Publications

Fischer, N. H., Day, J. B., and Reynolds, R. C., "In-Flight Servicing with STS", IAF Paris 1982.

Edgecombe, D. S., Fischer, N. H., and Rea, F. G., "WTR Operations with STS", IAF Rome 1981.

Mr. VOLKMER. Thank you very much, Mr. Fischer.

Again, I recognize the gentleman from New Mexico.

Mr. LUJAN. Thank you, Mr. Chairman.

I think your last statement, of course, is absolutely correct, that with the anticipation, a three-orbiter fleet is certainly not enough.

Let me ask you, which do you think, and I think you probably covered it in your statement, is the most likely, the 187 or the 104 launches over that 15-year period?

Mr. FISCHER. Our experience is that the low model has been a better estimator in the near-term, that is, the next year through 5 to 8 years out. Since we have been doing this from 1975, we don't have any experience based in projections that are 15-years out.

Mr. LUJAN. But aren't these projections based on 15 years?

Mr. FISCHER. Right. Yes.

Mr. LUJAN. Did you make some earlier projections and then some later projections? Did I understand that?

Mr. FISCHER. Annually, we project for a 15-year period.

Mr. LUJAN. How have those changed in the past, from your earler projections to your later, maybe I should say, assessments.

Mr. FISCHER. The trend has been an increased projection of number of payloads launched. For example, comparing the latest projection with one 3 years earlier is probably about a 25-percent increase.

Mr. LUJAN. Give me a figure of what you were projecting then. You are saying now 104 is more likely than the 187. What were you projecting 3 years ago? If you like, take that low model.

Mr. FISCHER. It is difficult to quote in terms of the low model, because 3 years ago we did not project in terms of equivalent shuttle flights but only in numbers of payloads.

Mr. LUJAN. I didn't look at your charts in terms of payloads, but you did have those figures in there, didn't you, the number of——

Mr. FISCHER. The number of payloads 3 years ago was about 25- to 30-percent less than what is there. I don't have the number offhand.

Mr. LUJAN. Then, it would have been around 300 instead of 435.

Mr. FISCHER. Right.

Mr. LUJAN. So that would mean 25 percent less launches, I would imagine, 75 to 104.

Mr. FISCHER. That is a good correlation, yes.

Mr. LUJAN. If you are talking about 104, you are talking about 7 launches per year over that 15-year period which is what your projections are for.

Mr. FISCHER. Yes. Right. That 104 is the total demand. The shuttle will not capture all that. That is total free world demand and not all will necessarily fly on shuttle in the low model.

Mr. LUJAN. Are you saying, then, that you will probably not fly 104 shuttle missions in the 15 years? Is that what you are saying?

Mr. FISCHER. The area that I am testifying on is only the commercial segment of the demand. There are NASA and DOD flights over and above that.

Mr. LUJAN. All right.

Mr. FISCHER. The commercial demand is typically about one-third of the total.

Mr. LUJAN. Well, that puts us in another area. If 104 launches were to be required for the entire demand throughout the world—that is what you are saying, over the next 15 years—of the commercial demand, and that being one-third of all the demand, are you then saying that there is enough capacity in both the defense and the commercial for 312 launches?

Mr. FISCHER. With NASA and DOD missions included. That would be for shuttle and Ariane, for example.

Mr. LUJAN. I am just trying to do some quick arithmetic, because we are not only looking at—If we are talking about 104 flights, we are not only looking at 7 flights per year—that is just for the commercial—twice that number for the defense needs.

Mr. FISCHER. The defense and NASA portions have to be added on, and typically they are each of equal magnitude to the commercial use.

Mr. LUJAN. That is kind of confusing. When I looked at that and I thought well, if we are just going to make 7 flights a year, that is not anywhere near the 24 that were talking about, but then you have to add to those, to the commercial ones, the defense ones.

Mr. FISCHER. Right.

Mr. LUJAN. Did I understand correctly that you were saying that the extended duration orbiter must come before the space station?

Mr. FISCHER. No. No, I only commented what it might be used for.

Mr. LUJAN. But that is not necessary in your——

Mr. FISCHER. In my viewpoint, it is not necessary.

Mr. LUJAN. Thank you, Mr. Chairman.

Mr. VOLKMER. I recognize the gentleman from Texas, Mr. Andrews.

Mr. ANDREWS. No questions, Mr. Chairman.

Mr. VOLKMER. The gentleman from Virginia.

Mr. BATEMAN. No questions, Mr. Chairman.

Mr. VOLKMER. Last week we had testimony from Under Secretary Aldridge about DOD and concerns about the space shuttle and possible going into ELV's in 2 years, 5 years, which would also put it in direct competition with up to 10,000 pounds for shuttle operation, and also, theoretically, makes it available for commercial

use. What impact would that have if that came about on your figures for shuttle utilization?

Mr. FISCHER. If I may try to restate your question. If there was an additional, commercial expendable vehicle available, what impact would that have——

Mr. VOLKMER. With a payload capacity of approximately 10,000, say, a range of 8,000 to 10,000 payload.

Mr. FISCHER. I don't think there would be a major change on the total demand. The only thing it would impact is the split in the demand as to how much shuttle captured, so then it would potentially, if the costs were sufficiently attractive to commercial customers, the schedules were flexible enough, insurance was available, and those other issues, it may take customers away from the shuttle to be launched on commercial ELV.

Mr. VOLKMER. In your analysis of the commercial demand, did you look into the weight of payload?

Mr. FISCHER. We have looked into the weight of the payloads in this. I can make a few comments on it. It typically has a tendency to be growing throughout the 1980's into the 1990's. There are some things that do tend to slow down that growth, such as technology improvements and crowding of the oval arc at geosync in terms of how many transponders you can put at single locations.

Mr. VOLKMER. So, there are things that offset the additional weight requirement that may——

Mr. FISCHER. For the commercial world, yes.

Mr. VOLKMER. Yes, I am talking about the commercial world.

Mr. FISCHER. Right. The materials processing area is one area where they do like the larger weights and that is predominantly going to be a shuttle related area anyway.

Mr. VOLKMER. Would an extended duration orbiter capability of, say, 14 or 15 to 21 days provide any positive benefit to the commercial community?

Mr. FISCHER. Yes, it would in the materials processing area. As I mentioned in my testimony, one of the drawbacks toward materials processing is the long leadtimes between R&D and first sale of product. Anything that can be done to try to reduce this time means investors are investing money over shorter periods of time which gives a better chance of generating capital necessary to make those kinds of investments.

Mr. VOLKMER. Would it be any impact, if any, if we had increases in launch costs, whether shuttle or ELV or anything, to the communications satellite payloads.

Mr. FISCHER. It would impact a portion of that market. There is basically different types of uses for communications satellites. There is both broadcast which is used primarily for cable TV, and there is no ground alternative, and there is enough profit being made that it would probably remain about what it is.

In the area of point to point communication, telephones and whatever, the fiber optics is an up and coming technology that can potentially become competitive with space communications. So, it could impact that segment of the market. For example, in 1988, a fiber optics cable is going to be laid underneath the Atlantic, and it will have the capacity of one Intelsat spacecraft, so it will reduce by one the number of launches that is likely to occur.

Mr. VOLKMER. Can you explain why the factors that you used to convert ELV launches to space shuttle equivalents are only one-half the size of the factors used by NASA?

Mr. FISCHER. There is—they aren't quite that much difference.

Mr. VOLKMER. What is approximately the difference? I understand that NASA uses a figure of approximately 0.25 on the Deltas and approximately 0.50 on Atlas Centaur.

Mr. FISCHER. Let's take the Delta as an example. NASA assumes that you can launch four Delta class payloads on the shuttle. In our computations, we base everything on the reimbursement policy and the assumption that you have an average of a 75-percent loaded shuttle. Doing this gives the case of five Delta class payloads on a shuttle instead of four, and it is not quite five, but just about that. With the increase in weight into the PAM D–2 class payloads, which exceed the current Delta, you no longer get into this situation. You are in a situation where you have four PAM D–2 class payloads can be launched on the shuttle, and it is consistent with the reimbursement policy.

Mr. VOLKMER. Which equivalency are you using in your model?

Mr. FISCHER. In all of our calculations when we show equivalent shuttle flights, those were 75 percent loaded flights, not 100 percent loaded flights.

Mr. VOLKMER. Yet, you still, in that, use the point——

Mr. FISCHER. We assume that——

Mr. VOLKMER. 0.14, 0.13?

Mr. FISCHER. The load factor for a Delta class payload is 0.14, 0.13 or thereabout, yes. And 0.14 times 5 is 0.7, which is roughly three-quarters of a flight.

Mr. VOLKMER. Yes.

Are you then saying that the equivalency used by NASA is a little high, then?

Mr. FISCHER. The four Delta class payloads may be what they can manifest on current flights.

Mr. VOLKMER. I see.

Mr. FISCHER. But it will not recover the cost if you have four flights with load factors of 0.14, on average.

Mr. VOLKMER. What are the major concerns of the commercial users regarding the space shuttle?

Mr. FISCHER. The major concerns?

Mr. VOLKMER. Yes, of commercial users.

Mr. FISCHER. They are that, of course, the price is always a concern. Schedule availability is a concern. When can we get on and have a launch date? Right now, the bookings are such that it is hard to get a confirmed launch schedule much less than 5 years in advance. Also, the amount of time it takes to integrate their payloads into the cargo in terms of both the physical integration times at the Cape and the paperwork involved.

Mr. VOLKMER. If we had five orbiters instead of four, would that alleviate any of these concerns do you think?

Mr. FISCHER. It would give the customer a better confidence that the schedule can be met and that when his payload is down, they are ready to go, that it will be launched.

Mr. VOLKMER. I have no further questions. Thank you very much, Mr. Fischer. We appreciate your testimony here today. You have been very helpful.

Our final witness is Mr. Phillip Salin, an economist.

Mr. Salin, your statement will be made a part of the record. You may either review it in full or summarize, however you so desire.

STATEMENT OF PHILLIP K. SALIN, ECONOMIST, VENTURE ACCELERATION, REDWOOD CITY, CALIF.

Mr. SALIN. Thank you. To begin with, Mr. Chairman, I greatly appreciate this opportunity to present my views on the harmful and, I believe, unintended consequences of NASA's proposed shuttle pricing policies. These policies have created an ongoing subsidy to shuttle operations which is significantly larger than has been generally realized. In turn, the subsidy is creating harmful disincentives, discouraging development of more cost effective American space transportation vehicles. While much of the data on which my findings are based is necessarily rough, I believe my overall conclusions will withstand careful, unbiased scrutiny, and will be borne out by coming events. Please note that I am not here representing any company. The views I am expressing are my own, as an economist interested in both the theory and practice of privitization and the introduction of competition in Government monopoly industries.

I will start by summarizing my conclusions:

One, the space shuttle is now and is expected to always be much more expensive to operate than was originally planned in 1971. I don't know anyone who disputes this. The only arguments are over how much more expensive it will be than originally planned.

Two, at this time, the shuttle is far more expensive for launching communications satellites to geostationary orbit than competing existing vehicles such as the Delta, Atlas Centaur, and Ariane. This is in large part because, unlike the expendable launchers, the shuttle has to cover the unavoidably heavy costs of supporting manned capability, as well as heavy costs of integrating multiple payloads on each mission. As a consequence of these unavoidable extra costs, the shuttle will always be more costly to operate for launching satellites than more specialized satellite launchers such as Delta or Ariane.

Three, although shuttle costs are falling and will continue to fall with experience, they are falling from a very high number.

Four, moreover, in coming years, and I recognize this is a controversial point, Delta and Ariane costs also can fall with time and experience.

Five, what is the short run on this? The current accounting data from NASA is consistent with all of these points, but NASA and its contractors have failed to make their implications clear to Congress. From the data, it appears that every shuttle launched during the next 5 years will cost more than $200 million but will be priced below $100 million. That is the shuttle pricing policy. It is $71 million in 1982 dollars which means it is about $80 million in 1986, and roughly $90 million in 1987, roughly $100 million in 1988.

The taxpayer pays the difference between this $200 million cost and this $100 million price. By contrast, the equivalent payload to one shuttle, as was, I believe, just discussed in the previous interchange, can be launched on existing Deltas—four Deltas can be launched—for a cost of approximately $120 million.

Six, as a result, every shuttle launched prior to 1989, carrying mainly commercial communications satellites will result in a waste of $100 or more of taxpayers money. I am saying a waste with respect to this number and not a subsidy. Other shuttle payloads may be subsidized; these payloads, as far as I can tell, involve straight waste.

Seven, another result of NASA's proposed pricing policy, the more cost-effective Delta and Atlas Centaur are being subjected to unfair competition by a taxpayer-subsidized shuttle. Unless immediate action is taken to change the shuttle pricing policy, these lower cost competitors may be driven out of business.

Eight, the longrun implications of the shuttle subsidies are even more serious. By discouraging development of more cost effective private American satellite launchers, NASA is guaranteeing that, in the long run, the only cost effective satellite launchers will be operated by foreign corporations. Following Ariane, I believe we can expect the Japanese to enter this potentially profitable market also.

For all three of these reasons—the unnecessary waste, the unfair competition, and the need to encourage the development of economically viable American competitors, shuttle prices should be raised to more closely approximate actual costs as soon as possible.

Once shuttle prices are raised to reflect actual costs, the shuttle's true merits will be easier for everyone to see. It has an obvious comparative advantage for manned missions, for complex research missions. Instead of wasting this unique capability on launching ordinary satellites which can be launched more cheaply by others, NASA should be following its charter and trying to get the maximum amount of research value out of the shuttle.

I believe there is somewhat the equivalent of a Copernican revolution going on in the thinking of many individuals in this country regarding their concept of NASA's proper role in the opening of the space frontier. I have seen this kind of a change once before at close hand. Back in 1975, I was fortunate enough to be one of the first economists in the United States to realize that AT&T was not, in fact, the beginning and the end of the telephone industry. It only thought it was.

While many people may believe that the deregulation of the telephone industry was avoidable, I do not. I believe it was necessary and inevitable, for better or worse, a natural consequence of the rapid progress our society has been making in science and technology, particularly in the last 20 years. It was unfortunate that AT&T fought progress and deregulation at every step of the way. AT&T had great difficulty recognizing that multiple, competing firms would be able to innovate and provide new cost effective services much more quickly than it had been able to do. Yet all of American's theoretical and practical experience in understanding free markets clearly demonstrates the positive impact of competition in promoting innovation and cost effectiveness.

About 1980, I realized that NASA, for all its sincere interest in promoting innovation and progress in space technology, had also, like AT&T, come to confuse itself with an entire industry: the space transportation industry. Instead of conceiving itself as the midwife that would help private firms like Boeing, Rockwell, General Dynamics, McDonnell Douglas, United Airlines, to enter an industry which already was becoming real and potentially competitive, NASA thought it had to do the job itself. It had begun to confuse the business of research with going into business.

Partly to try to visibly make this point, partly to try to make some money, and partly from a sense of adventure, along with certain other individuals, I set out on a shoestring budget in 1980 and 1981 to begin developing private companies whose mission would be to attempt something that at the time was thought completely impossible, to compete successfully with NASA at launching satellites into space and make a profit at it.

As a direct result of these efforts, I played a role and watched closely, so far, the development of this industry. Since 1980, to the surprise of many, these and other private firms, besides the ones I have worked with directly, so, adding to this list, General Dynamics, ComSat, et cetera, have begun seriously exploring the possibility of entering the private satellite launching business.[1] The purpose of my testimony today, will, I hope, explain why, as well as help convince you, that NASA's understandable desire to try to centrally plan the nature, composition, and future of the entire American space transportation industry from now on must be consciously resisted by Congress.

We need to see a very big change here, from the old NASA-centric view of the universe, from the idea of a national space transportation system, to the evolving development of an American space transportation industry.

Going into the more detailed part of my analysis, let me say first of all, that many of the facts I am basing my analysis on are not just my own opinion of the facts. There are many other people who believe these facts, and I believe this includes individuals not only in government in general and in aerospace companies, but even within NASA, especially younger people. The implications that I am drawing are perhaps more personal, although they also are not unique. However, I emphasize, I take full and solitary responsibility for saying these things and for the analysis I am presenting.

COSTS

As I will get into further, there are very high ongoing costs per launch of the shuttle. If we accept NASA's own projections of costs, budgets, and expected launch manifests—53 launches between fiscal 1986 and fiscal 1988—the average cost per shuttle launch during these 3 years, will be about $250 million. According to what my understanding of NASA's own expectations, meaning their numbers—they don't interpret their numbers this way—but as far

[1] The witness requested that this sentence be corrected to read: "Since 1980, to the surprise of many, private firms such as SSI, Starstruck, General Dynamics Comm Space, et cetera, have begun seriously exploring the possibility of enterng the private satellite launching business."

as I can tell, what the numbers say is that an average shuttle launch will cost about $250 million.

Please note that this number includes more than just what NASA calls operating costs. It also includes ongoing orbiter shuttle facility construction and improvement costs, a portion of the ongoing costs of conducting space tracking data and acquisition, a portion of ongoing costs of shuttle-related R&D, ongoing shuttle-related overhead labor costs. Note that this number does not include any sunk costs whatsoever, such as the $10 billion or more already spent on shuttle R&D, et cetera, orbiters, construction of facilities, and the operations during the first 2 years of development.

As I go into more detail in my text, I believe it is extremely likely that there will be unexpected cost increases, particularly in the operations cost—what NASA calls the operations cost—area. In 1983, NASA conducted four shuttle launches. By 1987, it expects to be conducting 20 shuttle launches annually. Although it is conceivable that NASA will be able to quintuple its volume service in 4 years without any major disappointments, I think this is unlikely.

Instead, it is reasonable to expect at least, I think conservatively, modest cost overruns, schedule slips, and unexpected maintenance costs, with the result that the average cost per launch will probably run closer to $300 million during this period. If you will, then, $300 million per launch represents my estimate of the probable average cost of conducting a shuttle program as NASA has defined it during the latter part of this decade.

I want to emphasize that, while I may have misallocated some numbers, I may have rounded some numbers wrong, or adjusted for inflation slightly differently, the only adjustment that I have made in any of the figures that it is my understanding are NASA's own numbers, this is the only adjustment I have made: I have increased their projections on total operating costs by 33 percent over the next 5 years, not 33 percent a year, just 33 percent higher in each year.

PRICES

NASA has proposed very low prices. The proposed pricing policy for 1986 through 1988 is not based on full cost recovery, on average annual cost recovery, on average per launch cost recover, or on any other methodology comparable to what a business-like firm would have to charge. Instead, NASA's pricing policy is based upon various concepts and analyses of its own design which, I am sure, have been carried out appropriately, because if you follow their logic, and you believe that logic is appropriate to plan on in this situation, which I do not, I am sure they have done their calculations appropriately.

According to NASA's internal analyses, the projected out of pocket costs for full shuttle launch in 1986–88 will be on average $71 million in 1982 dollars. NASA is proposing to charge as its launch price only this $71 million—and DOD will get slightly less. It is this disparity between average launch costs and the proposed

pricing policy, proposed charge,[1] that is the heart of the problem, the short-term problem, that I am talking about here. It will result in an increase in the Federal budget—and, as I will shortly argue, in part, an increase in the Federal budget.

What about marginal, incremental, out of pocket, and, a slightly different term sometimes quoted in NASA documents, additive costs? I have examined a wide range of methods for looking at shuttle launch costs, including especially NASA's budget estimates and figures presented to this committee. The attached exhibits at the back of my testimony present an attempt to put together the jigsaw puzzle of Shuttle costs. In a few minutes, I will come back to that and go through it. There are a number of important issues raised by these cost numbers.

Is NASA's marginal cost per launch below $71 million or above $71 million? If NASA's marginal cost was indeed below $71 million, as NASA administrators clearly believe, then every additional reimbursable payload pushed onto a shuttle makes a profit, and every additional $71 million shuttle flown makes a profit, whereas every satellite launch taken away from NASA results in a loss of profit, to the seeming detriment of the U.S. taxpayer.

This is critical and it explains a great deal of what has been going on. The logic is quite valid. It happens to cut equally sharply in the other direction. If NASA's marginal cost per shuttle launch is, in fact, above $71 million, then every additional payload pushed onto the shuttle results in an increased loss to the American taxpayer, whereas every satellite removed from the shuttle manifest saves money. The more the disparity between marginal costs and shuttle price, the faster we should be trying to get payloads off of the shuttle and onto reliable alternative means of transportation, such as Delta.

As far as I can tell from studying the numbers collected on the attached exhibits, the marginal cost of a shuttle launch in the 1980's will be no less than $150 million, and it is more likely to be approximately $200 million. It is absolutely critical to realize that questions of marginal cost are not theoretical questions of finding the one right way to calculate a number. They are intensely pragmatic questions of, in the real world, if I conduct one more launch in 1988, how much will my labor bill, parts bill, and overhead bill probably go up over what it would have, and if I conduct one less launch in 1988, how much will my total cash expenditures probably go down? How much will taxes go down?

Due to the limited availability of the kinds of analyses normally required to make such estimates, my numbers should only be taken as simple, rough, ball park estimates. The important question is not whether my numbers are rough or need to be polished, but instead, why they are so totally different from NASA's. There is a huge amount of difference between $150 million to $300 million and $71 million to $100 million.[2]

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[1] The witness would like to delete "proposed charge" and insert in lieu thereof "disparity between the $300 million average launch cost and the $71 million launch price."

[2] Footnote suggested by the witness for clarification: $150 million = low estimate of marginal costs 1988; $300 million = estimated average costs, 1986–88; $71 million = 1988 shuttle price, 1982 dollars; $100 million = shuttle price, 1988 dollars.

What is wrong with NASA's numbers? The cause of this situation is as follows: First, NASA has attempted to exclude many types of shuttle related costs from its pricing calculations.

Second, NASA has also attempted to exclude large parts of the total annual for even the included cost categories.

Third, and perhaps most important, even for what small amounts of cost were left, NASA has applied analytic methods almost guaranteed to result in cost underestimation. It has been averaging cost estimates from later years with cost estimates from early years. Since NASA's analysts are hoping that shuttle costs will drop dramatically all during the 1980's, the resulting average cost estimate used as the basis of NASA's proposed pricing policy is very low indeed.

As a result of all three of these factors at once—any one of them would not cause such a problem, but all three of them together—NASA and most other policymakers have believed that NASA is now or soon will be pricing above its cost when, in fact, it has been pricing far below the cost. I have already mentioned that this has perverse results.

Pricing according to very long-term cost estimates, wishes and hopes is something that no prudently manager of business ever could or ever would do. The matter of profitability of satellite launches is quite simple. If the average cost of a shuttle launch this year will be about $300 million, it makes no business sense to ask for all possible this year at a price of only $71 million. You might want to announce this year that by 1999, due to expected decreases in average costs, the price is expected to drop to as low as $71 million. This would be quite reasonable, but only when the average annual cost of a shuttle launch has in fact declined from the current $300 million per launch to the hypothetical expected $71 million costs, say around 1999—I recognize that NASA thinks it will be by 1987, but I think it will be later—only then does it make business sense to actually set the price at that level.

Even if marginal cost was the right number to set prices at, and I don't think it is, I know of no economic arguments for setting prices 3 years from now based on hypothetical marginal costs 6 years from now. Even on a marginal cost basis, shuttle prices in each year should be set at the estimated marginal cost of a launch in that year. If the marginal cost of a marginal launch will be $150 million or more until 1989 and possibly later, it is a complete waste of taxpayers' money to sell launches for less than $150 million between now and then.

Only with the shuttle has the U.S. taxpayer paying most of its bills is it able to maintain a price so far below both its average and marginal costs and not go bankrupt.

Now I wish to go to the exhibits at the back of my testimony. I am going to step through them very quickly; I can't take much time on them, but to try to give you an idea of what I am trying to present here.

The first page which has the overall title, "An Analysis of shuttle Cost and Price Projections;" the first line there, of course, is the expected number of launches out of Kennedy. This is NASA's own estimate, as I understand it.

The next section is really an analysis of the current budget proposal. The numbers that are in the first three rows, 83 to 85, as I understand it, are straight out of the NASA budget. I have looked at the NASA budgets and attempted to use these numbers; I have had to make certain assumptions based on limited information. For example, I am completely unable to tell what percentage of space tracking and data are budget—which, in 1985, are essentially $800 million, $795 million—is actually related to shuttle launch and early operations.

I have made an arbitrary assumption of 15 percent here. I want to emphasize that my conclusions would in no way be affected if that 15 percent was turned to zero percent, but I have tried to do the best I could on the estimates.

All of the other rows are out of the NASA budget. There could be arguments about whether I have misinterpreted some things and taken some costs that were not really shuttle related, but I don't think these numbers are going to change under careful scrutiny.

The main thing to notice here is that I have divided the total costs into two parts: operations which is what NASA calls total shuttle costs, and other shuttle related costs. So, I have got total shuttle other costs and total shuttle operating costs. The total of these two together in each year is what I call the total ongoing cost of the shuttle program.

It is important to note that the budget requests that are presented to Congress for operating costs, do not include the figure on reimbursements. To get the total expected shuttle operating cost, you have to add operating costs to reimbursements.[1]

Regarding 1986, 1987, and 1988, it is my understanding from various documents and so on, that this is NASA's expectation of what they expect to see in each of these cost categories. In particular, you notice in 1988, the 2.7 billion of total shuttle operations cost.

The next section—I have tried to provide a way of seeing numerically what happens when you exclude more and more costs and then you talk about total cost figures. So, the first line, total full costs I don't use anywhere else in my analysis. It is there for comparison. That is roughly what you would see if you were including some of the sunk costs.

Total ongoing costs is the number from the above analysis. Total operating costs similarly. Total out of pocket operation cost is an attempt to apply a NASA concept, out of pocket cost and give you some kind of comparison.

The bottom section is just showing very clearly how my own alternate estimates of operating costs were done and what their relation is to the other figures.

We move on to the next page. Here the attempt is to compare things on a per launch basis, in other words, to compare cost per launch, price per launch, increase in the Federal budget given NASA's pricing policy. I can't go through all of these different numbers here. NASA February 1984 numbers is my understanding of what NASA currently expects. NASA January 1982 numbers is

[1] For clarity the witness suggests the last clause should read ". . . you have to add budgeted operating cost to expected reimbursements."

a comparison of, as I understand it, the set of calculations that underlie the NASA pricing policy over time. That is where I have some information regarding what they were expecting operations cost to be over time and how they differentiated out of pocket operations cost from total operations costs.

I have provided, for humor value, the range of cost estimates possible in the additive cost versus full cost per shuttle launch. You see in 1983, for example, you can get anywhere from $50 million per shuttle launch up to $1.2 billion per shuttle launch, depending on which concept you are looking at.

Then I go into the alternate estimates and the bottom line. My bottom line, as I go into in the text, is that the average operating cost from 1986 to 1988 is going to be about $200 million for 53 launches in that period. The average ongoing cost, which is what I call average cost, is going to be close to $300 million, precisely, $284 million for 53 launches.

Regarding an attempt to estimate marginal cost, what I have done is the following: I have simply said, "Take the entire shuttle fleet, the shuttle number of launches in a year, and ask yourself whether you believe that 4 or 5 years out NASA could make one shuttle launch per billion dollars. If you believe this is true, then subtract $1 billion from the total ongoing costs and divide the remainder by the remaining number of launches." That is where my estimate of marginal cost comes from.

Price per launch I have tried to provide here since NASA price figures are often quoted in a way that is confusing and leads you to think that they are cost numbers which they are not. They are also quoted in different year dollars, 1975 dollars, 1982 dollars, and so on. I have tried to make it possible to compare on this page which number we are talking about here. If you see the $18 million figure, that is a quote for phase I in 1985 dollars.

Finally, I am led to the annual increase per launch in the Federal budget due to shuttle's pricing policy in different years. At the botton is an attempt to estimate, just taking an estimate of the number of commercial shuttles taken from shuttle's own manifests, what the total unnecessary increase in the Federal budget is due to the NASA pricing policy. I want to emphasize again that I believe my numbers are overall conservative.[1] I believe it is possible to show worse things than this, given reasonable expectations regarding the future.

Not only do I believe NASA is incorrect in trying to price today according to longrun estimates of a small fraction of its ongoing shuttle-related costs, I believe it is also incorrect in trying to set prices at marginal cost in the first place. The proper basis for prices in a Government-run business, in my opinion, is average annual cost. Any other policy results in the business becoming a political football in which different customer groups start vying with one another to get low prices, while all other customers have to pay more than average cost to make up the difference. Whatever

[1] The witness submitted the following statement for clarification: "Because I was using a cash basis accounting methodology, 1983–85 deficits are somewhat difficult to interpret. The reader may find it easier to follow the accrual basis exhibits I have attached at the back of the document titled 'Replies to Questions.' Also, the diagrams at the front of the 'Replies' document should provide a useful visual summary."

part of the tab is not picked up by the other customers is paid by the taxpayer as part of a continuing annual subsidy.

In addition to creating permanent requirements for taxpayer funding of operations, marginal cost pricing creates unfair barriers to entry by would-be competitors—barriers which are not in the public interest. When one competitor can price at marginal cost due to access to taxpayer funds to make up the difference between average cost and marginal cost, all other competitors will be forced out of business even if their average cost of providing service is lower than the subsidized service.

Very quickly, a bit about Delta costs. There seems to be no lower-cost way of performing manned missions right now than on shuttle, but the launching of ordinary satellites can and has been done at lower average cost and a lower marginal cost, also, than shuttle can match, I believe. This is the real explanation for shuttle's low prices. Only by pricing far below its average and marginal costs has shuttle been able to make it appear that Delta and Atlas were already economically obsolete.

Consider Delta economics. Each shuttle is capable of launching about four Delta class satellites, as we just heard. Together with the cost of upper stages, the operations cost, alone, of launching these four satellites on shuttle in 1986, I believe, will be about $250 million. The "full" cost of four Delta launches in 1983, as I understand it, was $120 million. This was without subsidy of any kind. "Operations" cost, "out-of-pocket" cost, and "additive" cost would all have been lower than this $120 million.

The existing shuttle price-cost subsidy not only results in waste and unnecessary burden on taxpayers, it also serves to crowd out competition. To provide perspective on just how much money $100 million is, $100 million is enough money to found a credible private space transportation company from scratch. There has already been at lease one case of an experienced group of aerospace engineers who sought to enter this business and failed, primarily due to their inability to raise initial funds. Satellite Propulsion Inc., a firm which was to have been headed by the former president of Aerojet, failed to get off the ground because it could not raise this commitment. The idea that NASA's proposed pricing policy is serving to crowd current and potentially lower-cost competition out of the marketplace should be taken very seriously by Congress.

What should NASA's shuttle price be? Full average cost pricing for the shuttle would involve, I predict, charging about $300 million per flight, to NASA for research, to DOD for defense, to commercial customers for whatever purposes. The shuttle simply isn't worth that amount of money to commercial customers. In that sense, for unmanned missions, it is not an economic success. Like Concorde, a lower price than would be needed to cover all ongoing costs will have to be adopted for shuttle, not as a sign of strength, but of weakness.

For manned missions and activities, it is up to Congress how much subsidy it wishes to make taxpayers pay indefinitely. I have no answers here. But for unmanned, ordinary satellite launches, I believe the price should be raised as soon as possible to at least $150 million per full shuttle launch. The $200 million would be closer to marginal cost, I believe, but $150 million would be suffi-

cient to get the basic message across: It is again OK for American firms to try to launch satellites more economically than NASA's shuttle is able to do it.

Shuttle is only part of the future, not all of it. Shuttle services need to be intensively reviewed in the light of the classic business concept of comparative advantage, including comparative cost effectiveness. What is shuttle best at? What is it worst at? NASA needs to be encouraged to concentrate on using shuttle for manned missions, complex scientific research, and so on, tasks for which it is uniquely suited. Raising the price of shuttle now will encourage NASA to begin transitioning from thinking of the shuttle as the whole future to thinking of it as just a part of the future, the primary part for right now, but still only one part of the emerging American space flight industry.

We need to change NASA's shuttle pricing policy now in light of these numbers, and so on. The signals need to be sent now. There is a need to alert customers now that shuttle is not economically viable in the long run for launching ordinary vanilla satellites.

There is a need to alert potential American competitors now that NASA will not be allowed in future to price below cost, continuing to discourage what would otherwise be rational investments in more cost effective transportation vehicles. I believe that the fear of unfair price and other forms of competition by NASA is the overwhelming reason that most of the major aerospace companies are not already competing at providing space transportation today. If the clear signal is given now, I believe they will be competing intensely by 1986.

Finally, there is the need to remind and stress to NASA employees and officials now that NASA's long run mandate is research and not the operation of businesses in the marketplace. NASA was intended and is expected to continue to do in the future what it has done so well in the past: Research. Just as communications satellite manufacturing and operations have been allowed to naturally emerge as competitive businesses without any obstructive policies by NASA, so the space transportation industry should in future be allowed to develop freely and competitively.

What are the consequences of letting the status quo continue? Basically, the bad things that I have been talking about will continue. In particular, if Congress fails to act now, the false signals which NASA has been introducing into the marketplace for over 13 years regarding actual shuttle costs will be perpetuated. As a result, investments will not be made to further improve the cost effectiveness of Delta, Atlas, and Titan, and prospective new entrants will be less likely to raise money to produce new vehicles that might lower space transportation costs faster than NASA has evidently been able to do it.

Moreover, having prevented private companies from successfully entering into competition with its taxpayer subsidized transportation service, NASA will be in a position to claim that there are further, new requirements to develop additional, taxpayer-funded components of its "national space transportation system."—We don't have a national airline system but we have a national space transportation system.

Already the trial balloons for shuttle follow-on and shuttle-derived launch vehicles are beginning to surface. These vehicles, too, will be subsidized from beginning to end, further preventing private companies from successfully entering the marketplace. Note that if shuttle follow-ons are not funded by NASA, this does not mean shuttle technology will be abandoned. It means the technology will be further developed on a more economical basis by private firms, rather than at public expense.

Between high shuttle operating costs and high costs of developing new advanced transportation, NASA's effective scientific and research budget will be squeezed down even further. The United States will obtain less research from an agency whose whole purpose is to conduct research and will instead receive inadequate space transportation service from a government agency trying to act like a business.

Finally, if Congress fails to act now as a result of all of these factors, 10 years from now, the American taxpayer will still be paying unbelievably high costs for space transportation, fully 23 years after the shuttle program was initiated, in large part, to provide America with low cost space transportation.

I have a few additional comments.

First, with respect to space commercialization in general, it seems to me that NASA has been reversing cause and effect. It is the emergence of low cost space transportation which will make many new forms of activity in space profitable, with the result that the amount of space transportation demanded will increase. It does not work the other way around. Adding a new activity to the total volume of space activity years before it in fact becomes profitable does not cause transportation costs to go down, or at least not very much. It does cause subsidy requirements to go up. Pretending that transportation costs are lower than they are does not encourage space commercialization and space entrepreneurs. It encourages, rather, malinvestment and premature investment of society's scarce research funds.

Whatever cost and pricing policy is finally adopted for shuttle, many kinds of research involving space activity will continue to be of interest to private firms. NASA should be encouraged to continue the outstanding job it is currently doing of talking to private firms and getting them to consider the possibility that they might be able to make money in space. However, NASA should be prevented from directly causing premature investments by would-be space entrepreneurs prior to the time when they actually have become profitable. That time only comes when all the costs actually faced by the entrepreneur, including actual shuttle transportation costs, truly look worth paying for. The key to all of this, in the future,is that NASA shifts more into an advisory role rather than a directing role.

Second, I am neither trained nor knowledgeable about defense concerns. I have few comments here; and I have recently learned about recent testimony from the DOD that, while certainly not the same as what I am saying, seems to me complementary to it.

Third, once NASA's role in space transportation is reformulated, it will be more able to concentrate on research, including science and applications satellites, exploratory missions, and space station

development. Its effective research budget, as opposed to transportation budget, will start to expand again. The people who joined NASA to practice science will again be able to do their jobs and leave the job of being in business to businessmen.

Fourth, The fifth orbiter appears to me to be unnecessary as far as commercial needs are concerned. However, I am no expert on the statistics of rocket malfunctions. I have trouble believing that one of the four orbiters won't be out of service for a significant length of time at some point in the next 6 years. This reason, or some specialized need of DOD, might justify the fifth orbiter. Perhaps the space station will result in a need for extra capacity, worth the $2 billion construction costs and $200 million per launch cost. The point is this: Provided shuttle launches are properly costed and priced, the question of a fifth orbiter to some extent will solve itself.

If the amount of shuttle service desired by DOD, NASA, and commercial customers at $200 million per launch is still sufficient to keep the manifest for four orbiters full, that suggests constructing orbiter 5. However, if the manifests slack up a lot, as I expect they will, orbiter 5 should not be approved.

Last, similar arguments hold for the many shuttle followon proposals. The hallmark of the next generation of American launch vehicle designs, I believe, should be that they are so economically attractive that private firms cannot wait to privately finance them and operate them. If Rockwell or other companies like it cannot come up with an idea good enough to want to back it itself with its own money, maybe the time has come for other firms to take the lead in space transportation. To put it a little differently, the only way to find out if Rockwell and these other companies actually have the right stuff of business is to encourage them to get out there and put their own funds at risk instead of mainly taxpayer money.

The shuttle is a wonderful manned machine, but it is not low cost. Yet lowering the cost of space transportation, I believe, is the main key to opening the space frontier. The next great breakthroughs in space will be economic breakthroughs, providing much lower transportation costs from Earth to low Earth orbit. Over the last two decades, first with Apollo and now with the shuttle, Americans have made great progress pushing the technical envelope of space transportation. Now it is time to focus on pushing the economic envelope by putting private American companies to work on solving the problem. American industry is now poised and ready to do this, provided it is not forced to fight an uphill battle with Government-subsidized competition.

Thank you.

[The prepared statement, plus answers to additional questions asked of Mr. Salin, follow:]

UNNECESSARY FEDERAL EXPENDITURES and HARMFUL DISINCENTIVES

DISCOURAGING DEVELOPMENT OF COST-EFFECTIVE SPACE TRANSPORTATION

CAUSED BY NASA'S SHUTTLE PRICING & COST-ACCOUNTING POLICIES.

TESTIMONY OF PHILLIP K. SALIN

PARTNER, VENTURE ACCELERATION
REDWOOD CITY, CALIFORNIA

SPACE SCIENCE AND APPLICATIONS SUBCOMMITTEE
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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EXECUTIVE SUMMARY:

1. The Space Shuttle is now and is expected to always be much more expensive to operate than originally planned in 1971. No one disputes this. The only argument is over how much more expensive it will be than originally planned.

2. At this time, the Shuttle is far more expensive for launching communications satellites to Geostationary orbit than competing vehicles such as Delta, Atlas/Centaur, and Ariane. This is in large part because, unlike the expendable launchers, the Shuttle has to cover the unavoidably heavy costs of supporting manned capability, as well as heavy costs of integrating multiple payloads on each mission. As a consequence of these unavoidable extra costs, the Shuttle will always be much more costly to operate for launching satellites than a more specialized satellite launcher such as Delta or Ariane.

3. Although Shuttle costs are falling and will continue to fall with experience, they are falling from a very high number.

4. Moreover, in coming years, Delta and Ariane costs will also fall with time and experience.

5. Current accounting data from NASA is consistent with all of these points; but NASA and its contractors have failed to make their implications clear to Congress. From the data, it appears that every Shuttle launched during the next 6 years will cost more than $200 Million but will be priced below $100 Million (Shuttle pricing policy). The taxpayer pays the difference. By contrast, the equivalent payload to 1 Shuttle can instead be launched on existing Deltas and Atlas Centaurs for a cost of approximately $100 Million.

6. As a result, every shuttle launched prior to 1989 carrying mainly commercial communications satellites will result in a waste of $100 Million or more of taxpayer's money.

7. Also as a result of NASA's proposed pricing policy, the more cost-effective Delta and Atlas Centaur are being subjected to unfair competition by a taxpayer-subsidized Shuttle. Unless immediate action is taken to change the Shuttle pricing policy, these lower-cost competitors may be driven out of business.

8. The long run implications of the Shuttle subsidies are even more serious. By discouraging development of more cost-effective private American satellite launchers, NASA is guaranteeing that the only cost-effective satellite launchers will be operated by foreign corporations; following Ariane, we can expect the Japanese to enter this potentially profitable market also.

9. For all these reasons, Shuttle prices must be raised to more closely approximate actual costs as soon as possible.

10. Once Shuttle prices are raised to reflect actual costs, the Shuttle's true merits will be easier for everyone to see: it has an obvious comparative advantage for manned missions and for complex research missions. Instead of wasting this unique capability on launching ordinary satellites which can be launched more cheaply by others, NASA should be following its Charter and trying to get the maximum amount of research value out of Shuttle.

SUMMARY OF HOW THE SHUTTLE PRICING PROBLEM DEVELOPED:

11. The cause of this situation is as follows:

- o First, NASA attempted to exclude many types of Shuttle-related costs from its pricing calculations.
- o Second, NASA also attempted to exclude large parts of the total annual cost for even the "included" cost categories.
- o Third, even for what small amount of costs were left, NASA applied analytic methods almost guaranteed to result in cost underestimation: it averaged cost estimates from later years (possibly seriously underestimated) with cost estimates from earlier years, and then based its prices on the calculated average. Since NASA's analysts are hoping Shuttle costs will drop dramatically all during the 1980's, the resulting average cost estimate used as the basis of NASA's proposed pricing policy is very low.

12. As a result, NASA and most other policymakers have believed that NASA is now or at least soon will be pricing above its cost, when in fact it has been pricing far below its cost all along.

13. This has had perverse results: whereas the taxpayer is in fact losing money unnecessarily with every satellite launched on the Shuttle that could have been launched otherwise, NASA has been trying to put every possible satellite onto the Shuttle, and taking every possible satellite off of the (lower cost) expendables. It should have been doing the exact opposite.

INTRODUCTION:

Mr. Chairman:

I greatly appreciate this opportunity to present my views regarding the harmful and, I believe, unintended consequences of NASA's proposed Shuttle pricing policies. These policies, in my opinion, have created an ongoing subsidy to Shuttle operations which is significantly larger than has been generally realized. In turn, the subsidy is creating harmful disincentives discouraging development of cost-effective American space transportation vehicles. While much of the data on which my findings are based is necessarily rough, I believe my overall conclusions will withstand careful, unbiased scrutiny, and will be borne out by coming events. Also, please note that I am not here representing any company. The views I am expressing are strictly my own.

Before launching into my findings, I would like to say something about how and why I became interested in the subject of Shuttle cost and price policies. My background is in economics, including expertise in the economics of regulated industries. I first became interested in the question of the commercialization of space 6 years ago, while completing my MBA and conducting certain private studies in cost and accounting theory at Stanford. The Shuttle was at that time already suffering from delays and cost overruns, while NASA was trying to develop what it conceived as "the" National Space Transportation System.

Previously, back in 1975, I had been fortunate enough to be one of the first economists in the United States to realize that AT&T was not in fact the beginning and end of the telephone industry; it only thought it was, as did most AT&T employees, regulators, economic analysts, and customers. While many people may believe that the deregulation of the telephone industry was avoidable, I do not. I believe it was necessary and inevitable, for better or worse, a natural consequence of the rapid progress our society has been making in science and technology, particularly in the last 20 years. What was most unfortunate was the way that AT&T fought progress and deregulation at every step of the way, and caused great harm to this country as a consequence. AT&T had great difficulty recognizing that multiple competing firms would be able to innovate and provide new, cost-effective services much more quickly than it had been able to do. Yet all of America's theoretical and practical experience in understanding free markets clearly demonstrates the positive impact of competition in promoting innovation and cost-effectiveness.

In 1980, I realized that NASA, for all its sincere interest in promoting innovation and progress in space technology, had also, like AT&T, come to confuse itself with an entire industry: the space transportation industry. Instead of conceiving itself as the midwife that would help private firms like Boeing, Rockwell, General Dynamics, McDonnell Douglas, United Airlines, TWA, Pan Am, or Delta Airlines to enter an industry which already was becoming real and potentially competitive, NASA thought it had to do the job itself. It had begun to confuse the business of research with going into business.

Partly to try to visibly make this point, partly to try to make some money, and partly from a sense of adventure, along with several other individuals, I set out on a shoestring budget in 1980 and 1981 to begin developing private companies whose mission would be to attempt something previously considered impossible: to compete successfully with NASA at launching satellites into space, and to make a profit at it.

As a direct result of these efforts, I have have played a major role in the

founding and early management of ArcTechnologies/Starstruck; I had a definite, but rather limited influence at the outset on GCH Inc/SSI; and, I believe, I have in an indirect way contributed to the emergence of Satellite Propulsion, Inc.

Since 1980, to the surprise of many, these and other private firms have begun seriously exploring the possibility of entering the private satellite launching business. My testimony today, I hope, will help explain why, as well as help convince you that NASA's understandable desire to try to centrally plan the nature, composition, and future of the entire American space transportation industry must from now on be consciously resisted by Congress.

Much more is at stake here than just Shuttle prices. What is also at stake is the question of whether we will or will not see the emergence of economically viable and cost-effective private American competition to counter the emerging private European, and eventually, private Japanese space transportation companies. If current policies are continued, it will prevent or seriously retard the emergence of effective competition within the United States; the only effective competition that will emerge will be on foreign shores, and America will lose the lead it has held until now in space. Is this exaggeration? I point out that America has perhaps already lost the economic (as opposed to technical) lead in space: as far as I can tell from publicly available information, Ariane is already cheaper than Shuttle for launching satellites to Geostationary Orbit; and although Shuttle costs will drop with further experience, so will Ariane's. Because it is a simpler vehicle, it is reasonable to assume that Ariane's costs will drop more quickly than Shuttle's; in which case Shuttle will never catch up with Ariane. Clearly, for manned flight, the Shuttle will remain the dominant vehicle of the 1980's. For complex scientific missions, the Shuttle also appears to have extraordinary comparative advantage. But for tasks such as launching ordinary satellites, I believe the evidence is now sufficient to demonstrate that the Shuttle's costs simply remove it from being economically viable in competition with other existing launch vehicles.

I. SHUTTLE PRICE IS NOT SHUTTLE COST:

1. HIGH ONGOING COSTS PER LAUNCH. If we accept NASA's own projections of costs, budgets, and expected launch manifest of 53 launches between fiscal 1986 and fiscal 1988, the average cost per Shuttle launch during these 3 years will be approximately $250 Million.

Please note that this number includes more than just "operating" costs. It also includes ongoing orbiter and Shuttle facility construction and improvement costs, a portion of the ongoing costs of conducting "space tracking & data acquisition", a portion of ongoing costs of Shuttle-related R&D, ongoing costs of maintaining Shuttle-related "space research and technology base" and ongoing Shuttle-related overhead labor costs. Also note that this number does not include any "sunk" costs, such as the $10 Billion already spent on Shuttle R&D, the $3 Billion already spent to construct orbiters, the $2 Billion already spent to construct facilities, and the $5 Billion already spent to conduct 8 Shuttle launch operations over the past 3 years. (Caveat: these sunk cost numbers are based on non-comparable analyses, and will need to be adjusted at a later date; at any rate, they are mentioned here just so we remember that they have in fact been paid: but they are not used in any of the numbers I will be discussing later in my testimony.)

2. LIKELIHOOD OF UNEXPECTED COST INCREASES. In 1983, NASA conducted 4 Shuttle launches. By 1987 it expects to be conducting 20 Shuttle launches annually. Although it is conceivable that NASA will be able to quintuple its volume of service in 4 years without any major disappointments, this is not likely. Instead, it is reasonable to expect at least modest cost overruns, schedule slips, and unexpected maintenance costs, with the result that the average cost per launch will probably run closer to $300 Million during this period. If you will, then, $300 Million per launch represents my estimate of the probable average cost of conducting the Shuttle program as NASA has defined it during the latter part of this decade.

3. NASA'S PROPOSED LOW PRICES. NASA's proposed pricing policy for 1986-1988 Shuttle launches is not based on full cost recovery, on average annual cost recovery, on average per launch cost recovery, or on any other methodology comparable to what a businesslike firm would have to charge. Instead, NASA's proposed pricing policy for the Shuttle is based upon a costing concept of its own design, which it calls "out of pocket costs." According to NASA's internal analyses, projected "out of pocket costs" for a full Shuttle launch in 1986-1988 will be, on average, $71 Million (in 1982 dollars). NASA proposes to charge as its launch price only this $71 Million. (DOD will pay a slightly lower price, based on an agreement it has with NASA regarding cost sharing and Vandenberg operations.)

4. RESULTING INCREASE IN FEDERAL DEFICIT. Shuttle's only other source of funds is the taxpayer. Each year, after deducting total reimbursements received by NASA from commercial customers, foreign customers, other civilian U.S. government agencies and DOD, all remaining Shuttle costs are paid by the taxpayer, and contribute their part to the Federal Deficit. Now because about 1/3 of Shuttle payloads during the 1980's will be from NASA itself and hence not reimbursed; because about 1/3 of payloads will be commercial/foreign and hence reimbursed at the $71 Million price just mentioned; because the remaining 1/3 of payloads, being DOD, will be reimbursable at less than the $71 Million price; and because the average cost of a Shuttle launch will be about $300 Million, it is clear that if Shuttle pricing policies remain unchanged, the amounts added to the Federal Budget over the next 5 years would be substantial; in fact, they would total approximately $20 Billion.

5. WHAT ABOUT MARGINAL/INCREMENTAL/OUT-OF-POCKET/ADDITIVE COSTS? I have examined a range of methods for looking at Shuttle launch costs, including especially NASA's budget estimates and figures presented to this committee. The attached sheet presents an attempt to put together the jigsaw puzzle of Shuttle costs. There are several important issues raised by these numbers.

A. Is NASA's marginal cost per launch below $71 Million or above $71 Million? If NASA's marginal cost was indeed below $71 Million, as NASA administrators clearly believe, then every additional reimbursable payload pushed onto a Shuttle makes a profit, and every additional $71 Million Shuttle flown makes a profit; whereas every satellite launch taken away from NASA results in a loss of profit, to the seeming detriment of the U.S. taxpayer.

This logic is quite valid, but it happens to cut equally sharply in the other direction: If NASA's marginal cost per Shuttle launch is above $71 Million, then every additional payload pushed onto a Shuttle results in a loss; whereas every satellite removed from the Shuttle manifest saves money for the American taxpayer. The more the disparity between marginal cost and Shuttle price, the faster we should be trying to get payloads off the Shuttle and onto

reliable, alternative means of transportation (such as Delta). And as far as I can tell from studying the numbers collected on the attached page, the **marginal cost of a Shuttle launch throughout the 1980s will be no less than $150 Million, and is more likely to be approximately $200 Million.**

It is critical to realize that questions of marginal cost are not theoretical questions of finding "the one right way" to calculate a number. They are intensely pragmatic questions of "in the real world, if I conduct one more launch in 1988, how much will my labor bill, parts bill, and overhead bill probably go up over what it would have?" "And if I conduct one less launch in 1988, how much will my total cash expenditures probably go down? How much will taxes go down?"

Due to limited availability of the kinds of analyses normally required to make such estimates, my numbers should only be taken as simple, rough, ballpark estimates. The important question is not whether my numbers are rough and needing to be polished, but instead why they are so totally different from NASA's. There is a lot of difference between $150 Million-$300 Million and $71 Million-$100 Million.

B. What is wrong with NASA's numbers?

First, NASA's price policy excludes whole categories of costs from considerations: all ongoing Shuttle-related costs defined as other than "operations" costs are excluded from the analysis.

Second, NASA's "additive" and "out of pocket" cost figures, besides excluding whole cost categories, are based on the idea that NASA operating labor costs are permanently fixed, regardless of quantity of service delivered; hence labor costs are completely or almost completely excluded as well. Is this supportable? Are all labor costs at NASA truly fixed, incapable of varying at all to reflect variances in Shuttle launch rates? In the short run, this may be partially true. But in the long run, this is not supportable for any labor category or any business, including space transportation.

Much of the difference between my estimate of $150 Million-$200 Million per launch marginal costs and NASA's numbers appears to be labor costs, both within "operations" (such as launch operations and mission operations labor) and without (such as Program Management labor).

Consider the following thought experiment: NASA is projecting Total Ongoing Shuttle-related costs for 1988 as being approximately $4 Billion. Are virtually all of these costs completely, totally fixed, as NASA's pricing policy would have us believe? Suppose NASA only had 1 Shuttle launch to conduct in 1988. Could it really not manage to do this 1 launch for, say, $1 Billion? If it could launch 1 Shuttle for $1 Billion, then one way of estimating marginal costs for the remaining launches is to divide the remaining $3 Billion by the remaining number of launches. In 1988 this is 19 launches. $3 Billion divided by 19 equals $158 Million.

Third, NASA's numbers reflect an attempt to use <u>estimated future</u> costs 5 or even 12 years out as bases for <u>present</u> prices. Yet everyone knows how easily future costs can be underestimated. For this reason, among others, real businesses don't charge prices today based on how low their costs are going to be someday in the distant future maybe if all goes well. They charge a reasonable price this year, enough to cover this year's average costs, and

then bring down prices no faster than their actual costs appear to be declining. Pricing according to very long term cost estimates, wishes and hopes is something no prudently managed business ever could or ever would do. Thus the matter of profitability of satellite launches is quite simple: if the average cost of a Shuttle launch this year will be about $300 Million, it is makes no business sense to ask for all possible business this year at a price of only $71 Million per launch. (Announcing this year that by 1999, due to expected decreases in average costs, the price is expected to drop to as low as $71 Million would, of course, be entirely reasonable). But only when the average cost of a Shuttle launch has in fact declined from the current $300 Million per launch to the hypothetical, expected $71 Million cost (say, around 1999), does it make business sense to actually set the price at that level. Even if marginal cost was the right number to set prices at (which it is not), I know of no economic arguments for setting prices 3 years from now based upon hypothetical marginal costs 6 years from now. Even on a marginal cost basis, Shuttle prices in each year should be set at the estimated marginal cost of a launch in that year. If the marginal cost of a marginal launch will be $150 Million or more until 1989, and possibly later, it is a complete waste of taxpayer's money to sell launches for less than $150 Million between now and then. Only because Shuttle has the US taxpayer paying most of its bills is it able to maintain a price so far below both its average and marginal costs, yet not go bankrupt.

Fourth, not only is NASA incorrect in trying to price today according to long run estimates of a small fraction of its ongoing Shuttle-related costs, it is also incorrect in trying to set prices at marginal cost in the first place. The proper basis for prices in a government-run business is average cost. Any other policy results in the business becoming a political football, in which different customer groups start vying with one another to get low prices, while all other customers have to pay more than average cost, to make up the difference; whatever part of the tab is not picked up by the other customers is instead paid by the taxpayer, as part of a continuing annual subsidy. In addition to creating permanent requirements for taxpayer funding of operations marginal cost pricing creates unfair barriers to entry by would-be competitors, barriers which are not in the public interest. When one competitor can price at "marginal" costs, due to access to taxpayer funds to make up the difference between average costs and marginal costs, all other competitors will be forced out of business even if their average costs of providing services is lower than the subsidized service.

6. DELTA, AND POSSIBLY ATLAS & TITAN ARE LOWER COST SATELLITE LAUNCHERS THAN SHUTTLE; YET THEY ARE BEING STRIPPED OF CUSTOMERS BY SHUTTLE'S ARTIFICIALLY LOW PRICES. There seems to be no lower cost way of performing manned missions right now than on Shuttle. But the launching of ordinary satellites can and has been done at a lower average cost, and a lower marginal cost also than Shuttle can match. This is the real explanation for Shuttle's low prices: only by pricing far below its average and marginal costs has Shuttle been able to make it appear that Delta and Atlas were already economically obsolete. Or that Shuttle is somehow cost-competitive with Ariane for launching geostationary satellites.

Consider Delta economics: Each Shuttle is capable of launching about 4 Delta-class satellites. Together with the cost of upper stages, the operations cost alone of launching these 4 satellites on Shuttle in 1986 will be about $250 Million. The full cost of 4 Delta launches in 1983 was $120 Million. This was without subsidy of any kind. "Operations" cost, "out of pocket" cost, and

"additive" cost would all have been lower than this $120 Million number.

Consider Ariane economics: I know of no publicly available comprehensive analysis of Ariane's costs. However, Arianespace is a separate organization from ESA, has shareholders, and claims to be able to make a profit at current prices. It is definitely subsidized in terms of R&D, but it may not be more than moderately subsidized otherwise. Starting in 1985, 2 Ariane rockets will be able to launch 4 Delta class satellites for a total price of only $100 Million. Even if ESA & CNES are moderately subsidizing Ariane operations right now, as I suspect they are, I also suspect that, due to the Ariane moving down its own experience curve (which is probably steeper than Shuttle's) the $50 Million/launch price will cover average cost of Ariane operations within 5 years, and possibly even produce a small profit. What would upset the long run potential profitability of Ariane is not further Shuttle subsidies, but the emergence of more cost-effective private American launchers. In this case, competition would push prices below $100 Million per 4 Delta class satellite launches, and Arianespace would have to follow suit to remain competitive.

Thus, it seems that both Delta and Ariane (and perhaps also Atlas Centaur and Titan) are more cost effective than Shuttle for launching ordinary satellites to geostationary orbit. If this is true, then NASA's attempt to pull geostationary satellites away from the competing expendable launchers is doubly wasteful: it wastes taxpayer money to support a subsidized launch, and it wastes both taxpayer and customer money to pay for a launch via Shuttle, for perhaps $200 Million, that could and should have been handled privately, for perhaps $100 Million. **Thus, every time a Shuttle full of ordinary geostationary satellites is launched, perhaps $100 Million of taxpayer money is unnecessarily wasted.**

7. THE EXISTING SHUTTLE PRICE-COST SUBSIDY RESULTS NOT ONLY IN WASTE AND UNNECESSARY BURDEN ON TAXPAYERS; IT ALSO SERVES TO CROWD OUT COMPETITION. To provide perspective on just how much money $100 Million is: **$100 Million is enough money to found a credible private space transportation company, from scratch.** There has already been at least one case of an experienced group of aerospace engineers who sought to enter the business and failed primarily due to inability to raise initial funds. Satellite Propulsion, Inc., a firm which was to have been headed by the former President of Aerojet, failed to get off the ground because it couldn't raise a commitment of $150 Million. The idea that NASA's proposed pricing policy is serving to crowd current and potentially lower cost competition out of the marketplace should be taken very seriously by Congress.

8. What should NASA's Shuttle price be? Full average cost pricing for the Shuttle would involve (I predict) charging about $300 Million per flight--to NASA (for research), to DOD (for defense), to commercial customers (for whatever purposes). The Shuttle simply isn't worth that amount of money to commercial customers. In that sense, for unmanned missions, it is not an economic success. Like Concorde, a lower price than would be needed to cover all ongoing costs will have to be adopted for Shuttle, not as a sign of strength, but of weakness. For manned missions and activities, it is up to Congress how much subsidy it wishes to make taxpayers pay indefinitely. I really have no answer here. But for unmanned, ordinary satellite launches, I believe the price should be raised as soon as possible to at least $150 Million/full Shuttle launch. $200 Million would be closer to marginal cost, I believe, but $150 Million would be sufficient to get the basic message across:

it is again OK for American firms to try to launch satellites more economically than NASA's Shuttle is able to do.

9. SHUTTLE IS ONLY PART OF THE FUTURE, NOT ALL OF IT. Shuttle services need to be intensively reviewed in the light of the classic business concept of comparative advantage, including comparative cost effectiveness. What is Shuttle best at? What is it worst at? NASA needs to be encouraged to concentrate on using Shuttle for manned missions, complex scientific research, and so on, tasks for which it is uniquely suited. Raising the price of Shuttle now will encourage NASA to begin transitioning from thinking of the Shuttle as the whole future to thinking of it as just a part of the future, the primary part (for right now), but still only one part of the emerging American space flight industry.

II. THE NEED TO CHANGE NASA'S SHUTTLE PRICING POLICY NOW.

In the light of these numbers and many other considerations, I believe that the $71 Million "out of pocket" launch cost, as NASA has defined and estimated it, is a totally inappropriate basis for Shuttle pricing policies. Moreover, I believe it will continue to do serious harm until a more appropriate basis for Shuttle pricing is implemented.

1. SIGNALS WHICH NEED TO BE SENT NOW. Beyond the need to make NASA begin bringing its costs and prices more into balance as soon as practicable for budgetary reasons, it is also important that the change in NASA's pricing policies be firmly and widely advertised at the earliest possible date, due to:

A. The need to alert customers now that Shuttle is not economically viable in the long run for launching ordinary "vanilla" satellites, and that planning to place such payloads on the Shuttle, rather than resulting in cost savings, may instead result in having to deal with costly unexpected delays, continuing price increases, and an overall worse deal than might be provided by Delta or Atlas/Centaur.

B. The need to alert potential American competitors now that NASA will not be allowed in future to price below cost, continuing to discourage what would otherwise be rational investments in more cost-effective transportation vehicles. I believe that the fear of unfair price and other forms of competition by NASA is the overwhelming reason that most of the major aerospace companies are not already competing at providing space transportation today. If the clear signal is given now, I believe they will all be competing intensely by 1986, possibly even earlier.

C. The need to remind and stress to NASA employees and officials now that NASA's long-run mandate is research, not competition in the marketplace; that NASA was intended and is expected to continue doing in future what it has done so well in the past, research; that just as communications satellite manufacturing, and operations have been allowed to naturally emerge as competitive businesses without any obstructive policies by NASA, so the space transportation industry will in future be allowed to develop freely and competitively.

2. CONSEQUENCES OF LETTING THE STATUS QUO CONTINUE. What will happen if Congress approves NASA's pricing policies, or allows them to slip by due to insufficient oversight? I believe that if Congress fails to reject these pricing policies, they will have a number of predictable effects severely detrimental to the public interest and the future of American progress in space. In particular,

A. If Congress fails to act now, the Federal Deficit will be increased unnecessarily by at least $100 Million every time a Shuttle is launched full of commercial payloads destined for Geostationary orbit. Current NASA projections show roughly 3 such Shuttles being planned for every year from now through 1988.

B. If Congress fails to act now, the false signals which NASA has been introducing into the marketplace for over 13 years regarding actual Shuttle costs will be perpetuated indefinitely. As a result, investments will not be made to further improve the cost effectiveness of Delta, Atlas, and Titan. And prospective new entrants will be less likely to raise money to develop new

vehicles which might lower space transportation costs faster than NASA has been able to do it.

C. If Congress fails to act now, existing vehicles which are able to launch geostationary satellites at a lower cost than Shuttle will be unfairly driven out of business. I am referring to Delta, Atlas, and Titan. If Congress was to give the clear signal that it is OK to invest money in cost improvements for these vehicles, their costs also would come down with time, just like Shuttle and Ariane. The net result would be that the full cost of launching a satellite on a Delta, Atlas or Titan might eventually decline to where it is lower even than NASA's current, highly subsidized price. But if Congress fails to act, precisely the reverse will be the case: Delta, Atlas, and Titan will be driven out of business; the customer will have to pay NASA for a Shuttle launch about the same amount he would have had to pay for a Delta/Atlas/Titan launch, and, in addition the public will have to pay 1-2 times this price in unnecessary subsidy/deficit/taxes.

D. Moreover, having prevented private companies from successfully entering into competition with its taxpayer-subsidized transportation service, NASA will be in a position to claim that there are further, new requirements to develop additional, taxpayer-funded components of its "National Space Transportation System." Already, the trial balloons for "Shuttle follow-on" or "Shuttle-derived launch vehicles" are beginning to surface. These vehicles too will be subsidized from beginning to end, further preventing private companies from successfully entering the marketplace. Note that if Shuttle follow-ons are not funded by NASA, this does not mean Shuttle technology will be abandoned. It means the technology will be further developed on a more economical basis by private firms, rather than at public expense. The worst thing that could happen here would be for the public to be made to pay for yet another non-cost effective transportation system instead.

E. Between high Shuttle operating costs, and high costs of developing new "advanced" transportation, NASA's effective scientific and research budget will be squeezed down even further. The US will obtain less research from an agency whose whole purpose is to conduct research, and will instead receive inadequate space transportation service from a government agency trying to act like a business.

F. If Congress fails to act now, as a result of all the above factors, 10 years from now the American taxpayer will still be paying unbelievably high costs for space transportation, fully 23 years after the Shuttle program was initiated, in large part, to provide America with low cost space transportation.

III. ADDITIONAL COMMENTS:

1. With respect to space commercialization in general, NASA appears to have reversed cause and effect in its thinking. **It is the emergence of low cost space transportation which will make many new forms of activity in space profitable, with the result that the amount of space transportation demanded will increase; it does not work the other way round.** Adding a new activity to the total volume of space activity years before it in fact becomes profitable does not cause transportation costs to go down: it only causes subsidy requirements to go up. Pretending that transportation costs are lower than they are does not encourage space commercialization and space entrepreneurs, but rather malinvestment and premature investment of society's scarce research funds. Whatever cost and pricing policy is finally adopted for Shuttle, many kinds of research involving space activity will continue to be of interest to private firms. NASA should be encouraged to continue the outstanding job it is currently doing at encouraging private firms to consider the possibility that they might be able to make money in space. But NASA should be prevented from directly causing premature investments by would-be space entrepreneurs prior to the time when they actually have become profitable. That time only comes when all the costs actually faced by the entrepreneur, including actual Shuttle transportation costs, truly look worth paying for.

2. Joint research endeavors are a different matter. NASA should be encouraged to conduct joint research with private firms on topics of mutual interest. As long as the full costs of NASA's help, including help with transportation costs, are clearly shown in the NASA budget, such research is a definite part of NASA's traditional mandate. The main thing to avoid in such joint research efforts would be either secrecy of results (publicly funded research findings should be made public) or implicit grants of monopoly. It is always possible to extort monopoly rents from activities which have no current effective competition. While the competing satellite launchers will to some extent act as a check on abuse of NASA's power in this area, it may be many years before an effective competitor emerges for manned activity in space. I would not expect NASA to grant such monopolies, or charge such monopolistic prices intentionally; it would be more likely to occur as a result of believing that a private company needs an "incentive" to take the risk of acting in space. While this may be true in some cases, it is nevertheless bad public policy. Such incentives are only subsidies of a different flavor.

3. As long as NASA continues to provide services in potentially competitive marketplaces, its costs, prices, and cost projections should be regularly audited by independent accountants from OMB, CBO, and GAO. The findings should be made available to private firms seeking accurate information about which specific NASA services have now become potentially profitable enough to begin being provided on a private basis, for profit, rather than on a public basis, for a loss.

4. NASA should be encouraged to work more often and more closely in future at helping private firms research and develop their own commercially-oriented, cost-effective space transportation systems. Working more closely with true profit-oriented concerns, NASA may be

able to help them do a better job of pushing the costs of products and services down, while at the same time keeping quality and reliability up. We are not dealing with an either-or situation here. We need both low-cost and reliability. The key here would be that NASA would advise, not direct. It would help with private research, but not provide funds. And NASA would specifically not be allowed to attempt any longer to direct, manage, or take an operational role in the development of commercially-oriented space transportation systems, or to try to pick "the one right way" to go to and from space. Choosing among different ways of providing goods and services on the marketplace is precisely the proper role of competing businesses, and not of government officials or committees.

5. I am neither trained nor knowledgeable about Defense concerns. I would expect the DOD to continue to play a major role in the development of the space transportation industry. I would expect it to develop its own vehicles, just as it develops its own fighter planes and personnel carriers. I would also expect it to often use the services of commercial providers, just as it often buys ordinary cars. One major long-run benefit for the DOD of encouraging the rapid development of competitive private space transportation will be the steady drop it can expect in the cost (and price) of space transportation. Since DOD's demand for space transportation is increasing quickly, it will be able to conduct more activities in space for a given budget the lower launch costs get. Also, the greater diversity that will emerge in the market will give the DOD more options regarding how and when to launch its satellites. It will have both Shuttle and other vehicles to call upon.

6. Once NASA's role in space transportation is reformulated, it will be more able to concentrate on research, including science and applications satellites, exploratory missions, and space station development. Its effective research budget (as opposed to transportation budget) will start to expand again. The people who joined NASA to practice science will again be able to do their jobs, and leave the job of being in business to businessmen.

7. The 5th Orbiter appears to be unnecessary as far as commercial needs are concerned. However, while I am no expert on the statistics of rocket malfunctions, I have trouble believing that 1 of the 4 orbiters won't be out of service for a significant length of time at some point over the next 6 years. This reason, or some specialized need of DOD might justify the 5th orbiter. Perhaps the space station will result in a need for extra capacity, worth the $2 Billion construction costs and $200 Million per launch cost. **Provided Shuttle launches are properly costed and priced, the question of a 5th orbiter will solve itself.** If
the amount of Shuttle service desired by DOD, NASA, and commercial customers at $200 Million/launch is still sufficient to keep the manifest for 4 orbiters close to full, that suggests constructing Orbiter 5. But if the manifests slack up a lot, as I expect they will, Orbiter 5 should not be approved.

8. Similar arguments hold for the many Shuttle "follow-on" proposals. **The hallmark of the next generation of American launch vehicle designs should be that they are so economically attractive that private firms**

can't wait to privately finance them and operate them. If Rockwell can't come up with an idea good enough to want to back it itself, maybe the time has come for some other firm to take the lead in Space transportation. Or, to say it differently, the only way to find out if Rockwell actually has "the right stuff" of business is to encourage it to get out there and put its own funds at risk, instead of mainly taxpayers' money.

9. The Shuttle is a wonderful manned machine, but it is not low cost. Yet lowering the cost of space transportation is the main key to opening the space frontier. The next great breakthroughs in space will be economic breakthroughs, providing much lower transportation costs from Earth to Low Earth Orbit. Over the last two decades, first with Apollo, and now with Shuttle, Americans have made great progress pushing the technical envelope of space transportation; now it is time to focus on pushing the economic envelope, by putting private American companies to work on solving the problem. American industry is now poised and ready to do this, provided it is not forced to fight an uphill battle with government-subsidized competition.

Thank you.

AN ANALYSIS OF SHUTTLE COST & PRICE PROJECTIONS 2-24-84
All dollar amounts in real $ (Millions)
all numbers rough

	81+82	1983	1984	1985		1986	1987	1988
LAUNCHES: #KSC/YR	4	4	8	11		13	20	20
ONGOING SHUTTLE COSTS:		Feb 84 Budgeted				Analysis based on NASA Feb84 data		
OPERATIONS:								
"operations costs"		1338	1402	1339		1250	1175	1200
plus: reimbursed opcosts		312	264	665		? 950	?1525	1500
TOT SHUTTLE OPER COSTS		1650	1666	2004		2200	2700	2700
OTHER SHUTTLE RELATED COSTS:								
Engr & Techn Base		70	93	105	?	105	105	105
Payload Oper & Supp Equi		44	53	61	?	61	61	61
Advanced Shuttle Transp		12	15	14	?	14	14	14
Construction		25	61	31		15	15	15
SpaceRes&Techn Base—SSh		24	24	26	?	26	26	26
Product, Oper, Capab Dev		1725	1649	1465		1200	825	421
15% ? of SpaceTrack&Data		72	101	119		119	119	119
Program Management		419	440	473		480	486	493
TOT SHUTTLE OTHER COSTS		2391	2436	2294		2020	1651	1254
TOTAL SHUTTLE ONGOING COSTS		4041	4102	4298		4220	4351	3954

"TOTAL" COST GETS LOWER THE MORE COSTS YOU EXCLUDE:
(All #s calculated using same Feb84 #s, Above:)

TOTAL "FULL" costs(incl sunk)	5041	5102	5298	5220	5351	4954
TOTAL "ONGOING" costs	4041	4102	4298	4220	4351	3954
TOTAL "TOT OPER" costs	1650	1666	2004	2200	2700	2700
TOTAL "OUT OF POCKET OPER" cst	912	1184	1364	1469	2240	2120

"ADDITIVE OPER" cost Less than any of above; not comparable

ALTERNATE ESTIMATES—Assumes opcosts 33% higher when #launches quintupls

TOTAL "ALT TOT OPER" costs (ALT OPER = OPER * 1.333)	n.a.	2221	2671	2933	3599	3599
TOTAL "ALT ONGOING" costs (ALT ONGOING = ALT OPER + OTHER SSH)	n.a.	4657	4965	4953	5250	4853

Note: If total Opcosts in 1983 were 1650,
Inflation alone at 6% implies 2082 by 1988 just to stay even.
A mere increase from 2082 to 2700 in 1988 when volume rises 400% over the same period seems unlikely.
A 33% increase over NASA's projections is thus very conservative.

	1983	1984	1985	1986	1987	1988
COST PER LAUNCH—DIFFERENT COST CONCEPTS as well as DIFFERENT ESTIMATES:						
NASA Feb84 #s: OPER, ry$	413	208	182	169	135	135
NASA Feb84 #s: OTHER SSH,ry$	598	305	209	155	83	63
NASA Feb84 #s: ONGOING,ry$ (ONGOING = OPER + OTHER SSH)	1010	513	391	325	218	198
NASA Jan82 #s: OPER, ry$	329	215	177	158	150	142
NASA Jan82 #s: OUT OF POCK,ry$ (OUT OF POCK = OPER-oper labor)	228	148	124	113	112	106
NASA Jan82 #s: OPER COST, 75$	155	96	74	62	56	50
NASA Jan82 #s: OUT OF POCK,75$	108	66	52	55	42	37
NASA Feb84: "ADDITIVE COST"	50	45	n.a.	n.a.	n.a.	n.a.
Contrast with FULL COST (FULL COST=ONGOING+sunk cost)	1260	638	482	402	268	248
ALTernate estimate of OPER (ALT OPER = OPER * 1.333)	n.a.	278	243	226	180	180
AVG ALT OPER 1986-1988: 191 MILLION for 53 launches						
ALTernate estimate of ONGOING (ALT ONGOING=ALT OPER + OTHR SSH) (=ESTIMATED AVERAGE COST)	n.a.	582	451	381	263	243
AVERAGE COST 1986-1988: 284 MILLION for 53 launches						
ESTIMATED MARGINAL COST: (MARG = TOTAL ALT ONGOING - $1 BILLION DIVIDED BY # OF LAUNCHES)	n.a.	457	360	304	213	193

PRICE PER LAUNCH:	.....PHASE 1...			.....PHASE 2...		
In 1975 dollars	18	18	18	38	38	38
In 1982 dollars	38	38	38	71	71	71
RY$ (assume 6% inflatn)	40	42	45	89	95	100
INCREASE PER LAUNCH IN FEDERAL BUDGET GIVEN NASA'S PRICING POLICY						
ALT ONGOING - PRICE, ry$	n.a.	540	406	292	168	143
MARG COST - PRICE, ry$	n.a.	415	315	215	118	93
TOTAL UNNECESSARY INCREASE IN FED BUDGET GIVEN NASA PRICING:						
# of commercial shuttles	1.66	2.00	2.66	4.50	6.75	5.25
(ALT ONGOING -PR)*#ComSh	n.a.	1080	1081	1314	1131	749
(MCOST - PRICE) * #ComSh	n.a.	830	839	968	793	486

		Pre-83 TOTAL?	1983	1984	1985	1986	1987	1988
SUNK COSTS:								
?	R&D: total?	10000						
	20yrs		500	500	500	500	500	500
	const: total?	2000						
	20yrs		100	100	100	100	100	100
	4orb: total?	3000						
	20yrs		150	150	150	150	150	150
	early ops: ?	5000						
	20yrs		250	250	250	250	250	250
	TOTAL SUNK?	20000	1000	1000	1000	1000	1000	1000

April 23, 1984

Chairman
Committee on Science and Technology
2320 Rayburn House Office Building
Washington, D.C. 20515

Phillip K. Salin
537 Cypress Street
Redwood City, Ca. 94061
(415) 366-2466

Dear Sir:

As per my discussions with Lynne Marie Draper and Vivianne Tessieri, I am returning a corrected copy of the transcript of my February 28 testimony before the House Subcommittee on Space Science and Applications. I am also including a copy of my written "Replies to Questions" for insertion as an Appendix to my testimony.

I have corrected the text to the best of my recollection.

I request insertion of a footnote referring to my "Replies to Questions" on the following pages: 62, 92, 109, 110.

I request revision of the transcript to correct garbled sentences on page 50 and page 106.

Finally, I request insertion of a few words or a footnote to clarify references on the following pages: 54, 56, 59, 80, 85

I understand that the Committee has strict rules regarding the transcription process. If I can be of any assistance in improving the transcript further I will do so quickly upon request. I remain honored by the opportunity to testify before the Subcommittee.

Sincerely yours,

Phillip K. Salin

MARCH 12, 1984

REPLIES TO QUESTIONS

REGARDING 2/28/84 TESTIMONY

ON SHUTTLE PRICING POLICIES

AND THEIR NEGATIVE EFFECT ON THE DEVELOPMENT OF

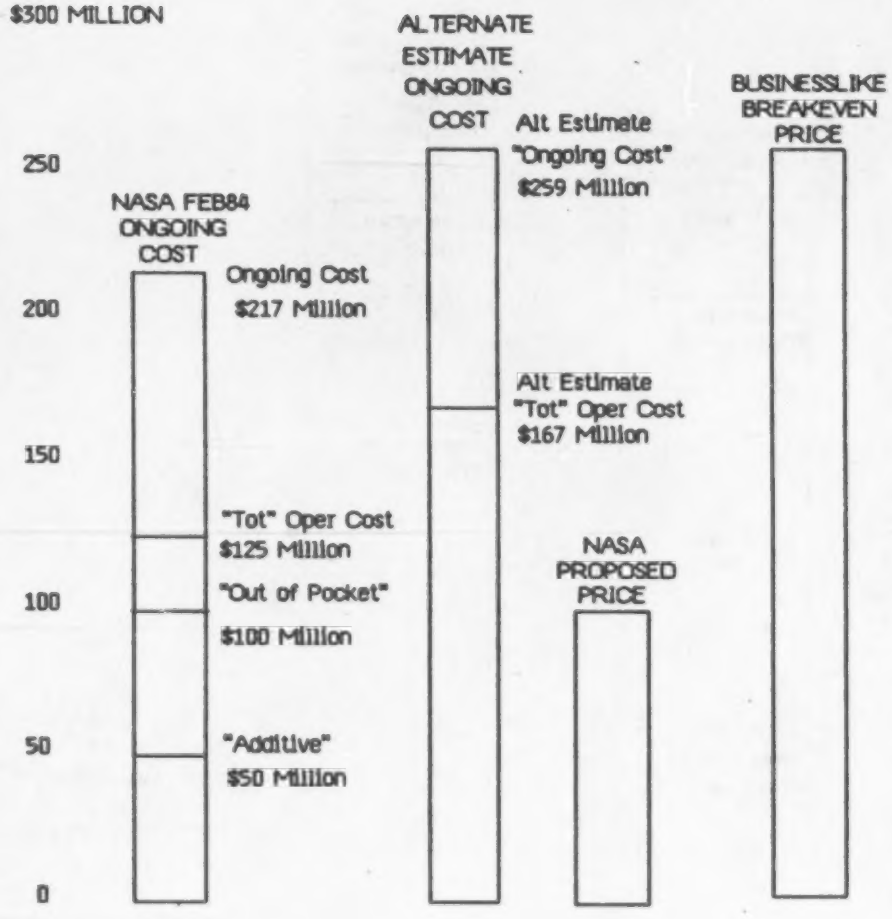
THE AMERICAN SPACE TRANSPORTATION INDUSTRY

PHILLIP K. SALIN
Economist

SPACE SCIENCE AND APPLICATIONS SUBCOMMITTEE
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

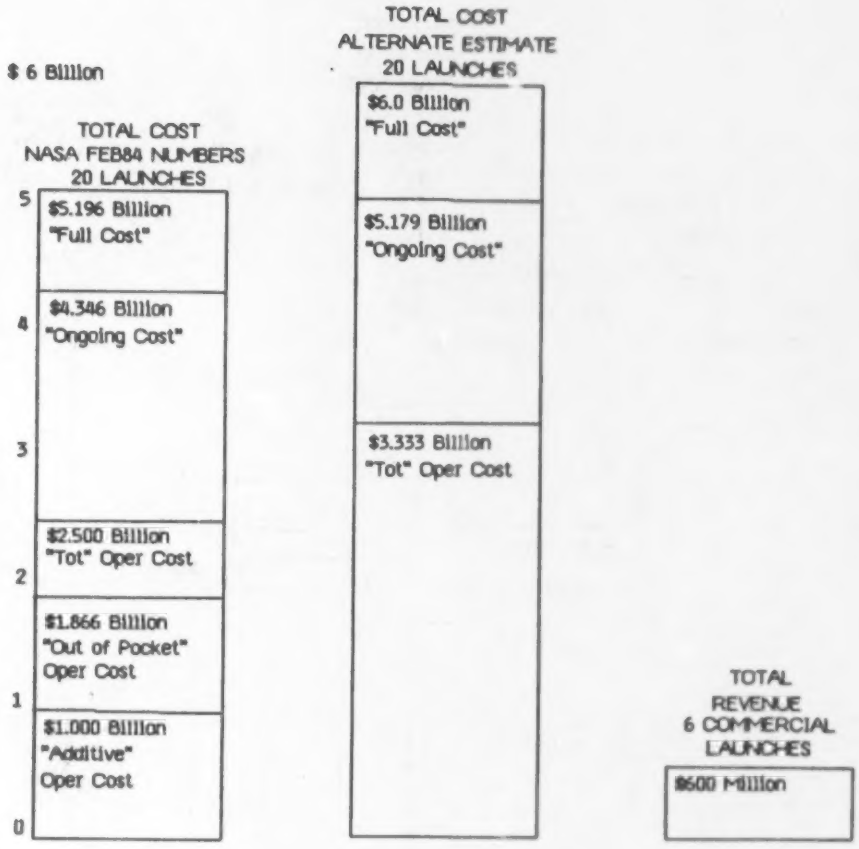
COST PER LAUNCH AND PRICE PER LAUNCH

1988 REAL YEAR DOLLARS



COMPARISON OF TOTAL SHUTTLE COST & TOTAL SHUTTLE REVENUE

1988 REAL YEAR DOLLARS



Preface to Questions and Answers:
The following text addresses each of the 15 questions that have been given to me. Taken singly or as a whole, I do not believe these questions significantly affect either my main findings or the conclusions I draw from them. Thus each of the policy-relevant points I have stated in the executive summaries to my testimony remain valid, as far as I can tell, despite the issues raised by these 15 questions. As part of my response, I have also revised my numeric analyses to try to take into account the factors raised by these questions. I have attached the results as Exhibits 1 - 6.

As I stated at the outset of my testimony, "While much of the data on which my findings are based is necessarily rough, I believe my overall conclusions will withstand careful, unbiased scrutiny, and will be borne out by coming events." After studying the questions which have been put to me, I feel even more confident that my rough estimates and analyses are defensible, and that my conclusions are correct.

Overall, the questions fail to address the most important issue raised in my testimony: how can a Boeing or a General Motors of space transportation ever emerge as long as Congress allows NASA to have the US taxpayer pay heavy operating subsidies for Shuttle, thereby making private space transportation appear uneconomic?

Questions and Answers:
I have grouped questions together where my answer addresses several questions at once. I have also rearranged the order of the questions to allow my answers to build on one another, and reduce redundancy in exposition.

Q1: Do you disagree with the concept of reusability as a means of saving money? Wouldn't airline fees be exorbitantly high if the aircraft had to be disposed of after each flight? Why shouldn't the same concept hold true for space transportation?

A1: Reusability versus Partial Refurbishability versus Expendability is sometimes treated as an almost ideological dispute; whereas, in fact, it is a complex pragmatic question of economic and technological tradeoffs. Reusability is one very important means, but not the only means, for attempting to lower space transportation costs. In each generation of space technology, reusability, like all strategies, reaches a point of diminishing marginal returns at some point. How far to push the idea of reusability, how quickly, and for which systems, is a decision the market is quite capable of making, and a decision which different firms will make differently in each technology generation. Note that: 1) Ariane intends to make its lower stage reusable, eventually; 2) The Shuttle itself expends hardware with each launch; 3) An efficient, totally expendable, non-manned vehicle conceivably may be cheaper per launch than any complex, manned vehicle such as the Shuttle, reusable or not; 4) Discussion of such trade-offs in an environment which habitually and conveniently "forgets" development costs paid by the taxpayer creates blinders to proper tradeoff analysis. Is a semi-reusable Shuttle which cost $20 Billion and 13 years to develop actually cheaper, for satellite launches, than a relatively inexpensively upgradable expendable such as the Delta or the Atlas-Centaur, or such as the Ariane, which cost only $1.5 Billion and a lesser number of years to develop?

Q2a: When the government develops facilities for its own national needs, do you believe that it is wrong for the government to allow commercial companies to use those facilities on an additive cost basis?

Q2b: Should the government end the practice of allowing ELV manufacturers to use government ranges on an additive cost basis? (Note, fully allocated costs would be at least several times greater.)

Q2c: The Delta and Atlas-Centaur were originally designed and developed with government funds. Should the government now assess all users of these ELVs a pro rata share of the original development costs?

Q2d: Why should the Space Shuttle be handled any differently--charging commercial customers for R&D and other investment expenses that the government must incur to meet its own needs?

A2: The four parts of this question inappropriately mix up the past, present, and future. They also mix my argument up in a way that will require some length to untangle.

To begin with, there are obvious and well-known differences between the decision environments which led to Delta/Atlas-Centaur and Shuttle.

A2a: Unlike either Atlas-Centaur or Delta, the decision to develop Shuttle was from the outset justified publicly as serving commercial needs as well as research and military needs. Current manifests show roughly 1/3rd of Shuttle payloads as commercial. I assume NASA would object to the idea that the Shuttle program has ever viewed commercial customers and commercial needs as being "marginal," either in size or importance. In this kind of situation, yes, I do think it is wrong to charge "additive costs" for use of government facilities. WHERE THE DECISIONS TO START OR CONTINUE A PROGRAM, TO CONSTRUCT FACILITIES, TO SPECIFY THE SIZE OF CAPABILITIES, TO DEFINE MARKETING STRATEGIES, OR TO SET TIMETABLES FOR THE DEVELOPMENT OF GOVERNMENTAL PROGRAMS HAVE BEEN INFLUENCED OR JUSTIFIED IN PART BY AN EXPECTATION OF FUTURE COMMERCIAL DEMAND, IT IS IMPROPER, AT A LATER DATE, TO DECLARE SUCH COMMERCIAL SERVICE AS "MARGINAL" FOR ACCOUNTING OR PRICING PURPOSES.

Also unlike either Atlas-Centaur or Delta, the Shuttle system is still being created. Projections of "Additive" or Marginal cost for a system under development are subject to underestimation for many reasons and to a far greater degree than for a system which is already smoothly operating at capacity and producing actual "steady state" cost data. Because Atlas and Delta are already operational systems, an accidental bias towards understating or overstating costs can at most distort their costs (and prices) by a factor of 2. For the Shuttle, a factor of 9 has already been achieved: in 1983, according to NASA's numbers, each Shuttle launch priced by NASA at $40 Million had an average "operations" cost of $363 Million (see Exhibits 4 and 5). Finally, unlike either Atlas-Centaur or Delta, Shuttle is a program so central to NASA's current activities, self-image, public-image, and budget that NASA has both maximum incentive and maximum opportunity to search for methods of presenting its future costs in the most favorable manner possible, and to refrain from publicizing the precise impact of possible developments which might negatively impact these future costs or which might draw attention to different ways of looking at the same figures.

Let me give a highly relevant example: Why does NASA assume that additive cost per Shuttle launch is currently adequately estimated by only adding up consumables costs? At least until 1987, and possibly until 1989, the Shuttle is a system under development, with capacity being expanded to its limit each year. It is at least possible, perhaps even likely, that attempting to cram an extra 2-3 launches into the schedule each year during the mid-1980's, while the Shuttle system is still under development, has resulted in a large total increase in the NASA budget directly attributable to pushing the program unnecessarily hard, unnecessarily fast. Marginal cost curves slope upwards whenever plant is being used near full capacity in each year. Now I have no doubt that the marginal cost of the marginal Shuttle launch will fall in most years until at least the mid-1990's. By 1995, indeed, the "additive" cost of squeezing in an extra Shuttle launch may well be only the cost of consumables, wear and tear on the orbiters, plus some variable labor costs, which by 1995 may only involve a total expense of roughly $100 Million. By then Shuttle may be smoothly operating at full capacity. But, as I understand it, the Shuttle manifest is very tight over the next 5 years, and a great deal of time, attention, and money is being spent on reducing turnaround time. The cost of adding each unnecessary commercial launch to the manifest in the next few years could be perhaps as much as $300 Million in added dollar costs alone. If additional costs in terms of strain on personnel, added risks of losing or damaging an Orbiter, or increased costs to payload owners due to trying to work with NASA's too tight schedule are counted (and they should be), even this $300 Million figure could be too low.

Note I am saying "could be"; how to estimate the actual additive cost of a marginal launch several years from now for a complex system under development and subject to slips, cost overruns, and even failures is not a question any two analysts or managers will easily agree upon. I do not expect my own estimates to be necessarily adopted. Their main purpose is to promote discussion and a careful, unbiased review of NASA's reasoning and NASA's estimates. As part of this review, I expect it will become apparent that the question of how to properly estimate "additive" or "marginal" cost for Shuttle launches 3-5 years from now is not as simple as NASA's analysts would have us believe. Indeed, the analytic problems inherent in attempting to estimate such costs is one of the many reasons marginal cost is a conceptually inadequate basis for pricing businesslike services in the real world. Back in the 1940's the idea of marginal cost pricing was quite in vogue among economists; however, there has been substantial progress over the last 40 years in understanding how and why the attempt to pursue marginal cost pricing causes unresolvable analytic problems, political problems, distorted incentives, and potentially huge resource misallocations. The proper basis for pricing of government services in a case like this, as I stated in my testimony, is average cost.

A2bi For this reason, therefore, yes, I do believe Delta and Atlas should be charged "average ongoing" cost, and not "additive" cost for their ongoing use of government facilities: any cash outflows which would otherwise be borne by the US taxpayer as a result of these activities, including R&D, construction, labor, and overhead costs, should instead be paid by the companies desiring to operate these vehicles. However, contrary to what is stated in the question, this would not result in multiplying the total cost per launch for these vehicles by several times.

First, the governmental facilities involved are only a part of total expenses

for these vehicles.

Second, whereas the total and per launch ongoing costs of supporting Shuttle, as I have documented, are quite large, the total and per launch ongoing costs of supporting Delta and Atlas are quite small. There is much less room for confusion and erroneous analysis here. The routine nature of the support required for Delta and Atlas will, I predict, make it possible for a small group of government accountants to come to a reasonable consensus rather quickly.

Third, even if it indeed was true that the ongoing cost of supporting tracking and range services for the private vehicles was large, done the government way, average cost pricing of these services would provide an incentive for the private firms involved to look for less expensive ways of obtaining these services, saving money for themselves and for society in the long run.

Finally, there appears to be some question regarding whether Delta launches have in the past been charged "additive" cost or not: following my testimony, a member of the audience informed me that Delta customers in recent years were, in fact, charged the full R&D and other costs associated with various capacity upgrades made in the late 1970's and early 1980's, and not just charged "additive" cost. I have not yet been able to double check this point, but mention it as an item deserving further investigation.

A2c & A2d: This part of the question mixes up past and future, and implies that my testimony argues for assessing future Shuttle users for past costs. This is not correct. The figures in my testimony for average ongoing Shuttle costs exclude past R&D ("sunk") costs, and include only future R&D costs. It is a classic economic fallacy to try to recover or "assess" past, sunk costs. The proper basis for discovering and realizing the present value of the Delta or Atlas would have been to auction the facilities involved and the associated rights to use and improve these vehicles to the highest reputable bidder. In the current Shuttle pricing environment, this would not have produced much revenue; the present fact and continuing threat of unfair competition by NASA has reduced the value of these facilities and rights to almost nothing. However, if NASA's announced prices had been set closer to expected average costs, the government might have obtained a much larger sum for the rights to Delta/Atlas, particularly back in the late 1970's and early 1980's.

Unfortunately, the erroneous conviction on NASA's part that expendable launch vehicles would be economically obsolete by 1983 has almost become a self-fulfilling prophecy: whereas ESA has invested in upgrades for the Ariane over the last few years, over the same time period NASA has neither invested in such upgrades nor encouraged private American companies to invest in upgrading the already-proven Delta and Atlas Centaur vehicles. As a direct result, over the last 5-10 years, both Delta and Atlas have fallen behind in terms of upgrades which could have been made and should have been made; any transitory weakness in the emerging competition between Ariane and Delta/Atlas should be attributed, at least in part, to NASA's attempt to suppress these vehicles and entice payloads onto the Space Shuttle sooner than was in fact economic. Both General Dynamics Commspace (with the Atlas) and Transpace Carriers (with the Delta) will have to make continuing R&D investments in their vehicles in the future to keep them competitive. Since these future costs will be borne by the companies involved, they must be reflected in their prices charged to

customers in order to stay in business. For this reason, contrary to the implications of the question, my testimony in fact argues for, and not against, comparable treatment for Shuttle and Delta/Atlas in stating that future Shuttle prices should reflect full ongoing (i.e. all future) costs of the Shuttle program, including future development costs.

Q8: Even if the government decided that it would charge commercial customers for a share of Space Shuttle R&D costs, are you aware that the vast majority of the current Space Shuttle R&D effort (filament wound solid rocket motor cases and 109% main engines) is to meet DOD and NASA needs--not those of commercial customers?

A8: No, I was not aware of this claim, or of any internal figures used by NASA to justify it. I had no access to any NASA internal analyses which break out estimates of how much of currently planned future Shuttle-related development costs NASA currently believes are to develop capabilities which NASA currently believes will be totally unutilized by future commercial customers. One of my main points is that such analyses are being made privately, without public scrutiny (in terms of timely, clearly presented, comprehensive analysis), and in a complex analytic, accounting and political environment; that therefore, summary numbers such as have so far been made available must be subject to multiple interpretations, until NASA shows otherwise.

For example, I will admit to some surprise over this matter of the 109% engine and filament wound case R&D costs. Contrary to what is stated in the question, I had thought that achieving the full 65,000 Lb Shuttle design capacity was relevant to commercial users, since a number of manifested launches which involve primarily commercial cargo utilize that full capacity. For example, STS39, according to the August 1983 manifest, shows a total weight of 65,632 lbs delivered to 160 nautical mile altitude to launch Satellite Television Corp DBS-B, RCA DBS-1, and UNISAT-1, plus a DOD PAM-D2 satellite. The only possible explanation is that NASA plans to launch STS39, and other such launches without using either the 109% main engines or the filament wound solid rocket motor cases. I have so far been unable to verify how NASA is planning to do this.

Q11: When a new business begins operation, is it not common for operating costs to decline as the business base grows? Given this fact, is it not common practice for new businesses just starting out to base customer fees on projected average costs over a 3 to 5 year period? (It would not be competitive to charge "actual" costs for the first year or so while sales are low.) Why is a similar practice not fair for the Space Shuttle?

A11: This question mixes up several issues.

To begin with, as I emphasized in the executive summary to my testimony, the problem with Shuttle pricing policies is that NASA has done at least 3 inappropriate things simultaneously in terms of cost exclusion and cost underestimation. Any 1 of these is much more defensible than all 3 taken together. Thus this question seriously misstates, by implication, the magnitude of what NASA has done.

First, most important, and directly contrary to the statement made in this question, NASA's Shuttle launch cost estimates and proposed pricing policies are not based on projected average costs, but on projected "out of pocket"

costs, which are less than 40% of average costs in every year through 1988, year 17 of the Shuttle program.

Second, as a rather minor point, the Phase 2 pricing policy, proposed (as I understand it) in mid-1982, attempted to set prices for the years from 1986-1988. This is 4-6 years later, not 3-5 years later.

Finally, these prices do not look at costs over the entire coming period, i.e., as a moving average which falls continuously from year 1 to year 6 in line with actual experience. Instead, they look only to projected theoretical costs starting 4 years out, and ending 6 years out. As a consequence, the normal mechanism by which real businesses "anchor" their future prices to present and past experience is thereby cut. I do not object to NASA's assuming that Shuttle's per launch costs will drop over the next few years. I object to their basing their proposed prices first on inappropriate accounting categories, and second on the assumption that the costs for these categories will drop extremely far, extremely quickly, all without providing clear, comprehensive, and publicly reviewable support for these figures. The anti-competitive incentive for NASA to "promise" Congress in 1983 that Shuttle costs will be low by 1988, and then be "surprised" in 1988 when it becomes obvious that they aren't, should by now be clear. When this happens, and I predict that it will happen, it will be pointless to say "We should have changed Shuttle prices earlier." The time to re-establish Shuttle pricing policies on more conservative accounting bases and estimates of future costs is now, not 1988.

Q10: In a competitive market, is it common practice for a company to set its prices to recoup all of its investment costs in the same year in which the investments are made? Are you aware that this is what you are arguing should be done with Shuttle R&D and investment costs? If the government were to charge customers fees to recoup its investment, wouldn't it make sense to at least amortize those costs over the useful lifetimes of the assets involved?

A10 (and continuation of A11): With respect to what is common practice for a company in terms of recouping investment costs in the early years of a project, I am surprised that this issue is being emphasized. Common business practice for new companies or new product lines is to charge as high a price as possible early on, in order to recapture as much of the development costs as is possible before competition from new entrants starts to cause prices to drop. In the first few years of a project, development costs frequently have to be amortized, particularly for heavy plant and equipment. But as a project proceeds, every attempt is made to use current prices to cover ongoing development costs such as "value engineering" costs, rather than deferring recovery until later. Prices are therefore set well above variable costs from an early date, and definitely by year 12 of a project.

Instead of paying attention to this dominant effect, NASA appears to have been confused by two distinctly second-order effects: first, awareness that a price discount, below average cost and sometimes even below variable costs, is often used in the first year of service to get customers to try a new service or a new supplier; and second, awareness that prices quoted for this year by aggressive competitors who expect their average costs to drop by next year are indeed often slightly below this year's expected average costs; but they are normally above next year's expected average costs!

Thus, common business practice would have meant that Shuttle would be charging high prices in the early years, not low prices; as a result, Shuttle prices would then have approached the eventual (lower) average cost figure from above, not from below as NASA is currently doing. The unnecessary and uneconomic attempt to replace Delta and Atlas-Centaur prematurely would have been avoided. The resultant waste in taxpayer's money would have been avoided. The improper disincentive to the development of private American space transportation companis would have been avoided. Shuttle prices would have started dropping only in parallel with actual average annual Shuttle-related costs, including as much of each year's Shuttle-related investment costs as market conditions would allow. I entirely agree that, given stiff competition emerging from Ariane, Delta, and Atlas Centaur, Shuttle will have to amortize its ongoing R&D expenses and attempt to recover their cost over future years. Such pricing strategies are followed by businesses not because they want to, but when they have no choice.

Numeric Response to Question 11: In order to show the (modest) impact on my estimates of 1986-1988 costs of amortizing future Shuttle-related investments over future years, I have calculated the exhibits attached to this document on an accrual basis, rather than on the cash basis used in my Testimony. In my Testimony I had to choose between making my overall analysis as easy to follow as possible, versus trying to make adjustments for every possible criticism. Given the status quo, in which no publicly available analysis from NASA clearly showed and compared projected Shuttle prices and expected total ongoing Shuttle-related costs, I chose the simplest possible approach and utilized a cash basis accounting methodology. For all the reasons just mentioned, I think this quite defensible. However, to respond to these questions regarding amortization and pricing strategies, I have revised my calculations as shown in the exhibits at the back of this document to reflect a more complex analysis, including an attempt to amortize future Shuttle R&D and investment costs over future missions, as requested.

As part of this analysis I have distributed costs from the "Total Production and Capability Development Costs" category as broken down in the NASA 1985 budgets in the following manner: I have subtracted and ignored costs associated with the final years of Orbiter production because I instead charge for Orbiter Use, pro rata, with each launch; I have expensed Orbiter Spares costs in each year; I have amortized the remaining Capability Development Costs, along with Construction costs (which appear low to me, but which I have nevertheless accepted as reported).

The effect of all this is to transform "Total Ongoing Costs" from a cash basis average cost concept to an accrual basis average cost concept. Please, note therefore, that Total Ongoing Costs in the exhibits attached to my February 28th Testimony is essentially an estimate of Total Shuttle-related Cash Costs in each year; by contrast, in the exhibits attached to the back of these questions and answers, Total Ongoing Costs is defined as Shuttle-related annual expenses on an accrual basis. The difference between Total Cash Costs and Total Ongoing Costs is shown in Exhibit 2. The biggest impact of this shift is on the numbers shown for 1983 - 1985, because cash outlays in this period are well above attributable annual expenses. With respect to 1986-1988, which has been the main focus of my attention and the focus of my stated conclusions, there appear to be no major changes or surprises. As far as I can tell, my conclusions as stated in the Executive Summary to my testimony are not in any way significantly affected by these adjustments.

Q13: What evidence can you cite to support your assertion that cost overruns, unexpected maintenance costs and schedule slips will drive the Space Shuttle cost per launch to $300 Million by 1987?

A13: This question implies that I am claiming Shuttle costs will rise to $300 Million per launch. Rather, I am claiming they may not have fallen much below $300 Million per launch by the 1986-1988 timeframe, which is a very different matter. (To be precise, my February 28 Testimony estimated $284 Million in Real Year 1988 Dollars as being the Average Ongoing Cost per Shuttle launch for 1986-1988. Exhibit 5 shows a revised estimate of $273 Million, resulting from average costs of $306 Million in 1986, $265 Million in 1987, and $259 Million in 1988, all in Real Year Dollars. This $273 Million estimated average cost per Shuttle launch for 1986-1988 is equivalent to $215 Million in 1983 Dollars: $215 Million cost per launch represents a very large drop from $581 Million per launch in 1983, (minus 63 percent!), and not a rise as implied by the question.

Thus the $273 Million figure is not a pessimistic number. It is an optimistic number. It is only slightly less optimistic than NASA's estimates, and it is based on the same broad scenario in terms of expected number of launches. As Exhibit 3 shows, NASA's numbers, as far as I can tell, imply that operations costs per launch will drop by 75% from 1983 to 1988. This could conceivably happen, but, given the range of possible outcomes, seems an overly optimistic figure to use as an estimate of the expected value. It therefore appears that NASA has underestimated the per launch operations costs it will probably achieve, and instead based its pricing calculations on per launch costs that it might possibly achieve. The alternate estimates increase NASA's projected operations costs per launch by 33% in 1988, and a lesser percentage in earlier years (See Exhibit 3). This is equivalent to saying that they assume that NASA will only achieve a 63% reduction in its per launch operations costs by 1987, rather than a 75% reduction, in constant dollar terms. I continue to believe that this is a conservative estimate, and that more pessimistic outcomes are possible or likely.

Why did I assume only a modest disappointment in NASA's expectations? First of all, I did not want to make any adjustments to NASA's numbers that would be so large as to make any of my major conclusions rest on such adjustments. As can be seen from Exhibit 4, even NASA's numbers suggest that the Shuttle price in 1988 should be $217 Million, and not $100 Million. Second, I wanted to show the potential impact of even small underestimates and misallocations on NASA's part regarding its future costs per launch. The 33% number is strictly by assumption, and based on consideration of what kinds of cost overruns and implementation delays frequently (even normally) occur in development programs in other parts of government as well as in private industry. Thus, my evidence to assert that the average cost per launch for Shuttle will be approximately $300 Million in 1986-1988 is NASA's own numbers, viewed, as I believe is entirely warranted, from a perspective of what seems likely, and not just what is conceivable.

Q3: In developing your cost estimates, did you have access to detailed government cost data on the Space Shuttle? What was the source of your cost information? Aren't the numbers in the budget documents at a highly aggregated and summarized level? Given that NASA of course has a much more detailed set of cost numbers available for its use, do you believe that, for any given set of accounting ground rules, your cost estimates are better than NASA's?

A3: My cost estimates are based in all cases on NASA numbers. Even the Alternate Estimate of Operations Costs, as explained above, is based on NASA figures. Also, throughout my numeric exhibits, I have taken pains to distinguish NASA's estimate of Operations Costs from the Alternative estimate, to allow scrutiny of NASA's numbers in the absence of any change, and to make it possible to see how my analysis would be affected (or not be affected) by different alternative estimates. Where I have only had data points to work with, I have made conservative interpolations or categorizations according to such information as I could find in the public record or otherwise attributed to NASA. I would have much preferred to be analyzing comprehensive reports by NASA on the issues I have discussed; however, such comprehensive reports, if they exist at all, do not appear to be publicly available. So I have had to make do.

The numbers I am working with are indeed highly aggregated and summarized. This is not necessarily a disadvantage. To spot a macro problem, looking at macro figures is often necessary. Correctly focussed detailed analysis often proceeds only subsequently. Public policy analyses related to Shuttle pricing have so far perhaps been overly concerned with minute items and short term considerations, while being underconcerned with maintaining perspective on the overall picture, such as the long run negative effects on development of a viable American space transportation industry. At any rate, I would welcome a timely, careful, comprehensive, detailed, and unbiased analysis of reasonable estimates for future Shuttle costs, and their proper allocation. This job should be performed by a team of professional government accountants independent of NASA, such as are found at CBO, OMB, or GAO, working with NASA accountants and representatives of a conventional business accounting firm such as Price Waterhouse or Arthur Anderson. The results would be more likely to be businesslike, logically consistent, and capable of adapting to measured costs of actual Shuttle operations, displacing hypothetical long term estimates as a basis for pricing.

Finally, of course I believe NASA is capable of estimating costs more precisely than I am able to for a given set of accounting ground rules. However, this question implies a situation somewhat at variance with the facts. First, as I have argued, NASA has only attempted to estimate its costs according to an inappropriate set of accounting ground rules, and not a businesslike set of ground rules. Second, there appear to be reasonable grounds for questioning NASA's projections regarding future cost-reduction achievements, such as how quickly NASA is likely to be able to achieve 75% reductions in its per launch Shuttle operating costs. But as I have argued in my testimony and in my answers to previous questions, it is precisely such conservative estimates of appropriately accounted numbers which should underly any proposed pricing policy. At a minimum, a range of possible outcomes for eventual Shuttle average ongoing and operating costs per launch should have been submitted to Congress and to the public for review, accompanied by careful supporting analysis, as part of any proposed Shuttle pricing policy. I can find no evidence that such sensitivity analyses have ever been submitted to Congress by NASA. I assume that NASA has conducted such sensitivity analyses, but do not know this either.

Q15: You have tried to compare NASA's "out of pocket cost" policy with other cost recovery models and concluded that the former is somewhat lower by a substantial amount (Note: "out of pocket" policy is meant to provide a basis for accomodating other foreign and commercial payloads after all federal needs are met, not a means to have foreign and commercial payloads pay for Federal costs.) Wouldn't your alternative policies result in the private sector subsidizing the government?

A15. No. The word "subsidy" is being semantically misused here. Any business or government agency offering services on the market is subsidizing a customer group (or "offering an unusually good deal") as long as the price charged is less than average costs of doing business. To put the point conversely, as it normally faces the businessman: every customer group which is allowed to get by paying less than average costs is an additional sign of impending bankruptcy. Only companies in financial or competitive trouble charge major customer groups lower than average cost. Right now, NASA is heavily subsidizing commercial customers. Depending on how you look at it, this subsidy is either coming out of NASA's research budget or out of the taxpayer's pocket. Reducing these heavy operating subsidies by raising Shuttle prices is hardly accurately described as creating a subsidy. Removing or reducing a subsidy is not the same as creating a subsidy.

As support for this average cost Shuttle pricing concept, Exhibit 5 shows roughly what basic Shuttle transportation prices (exclusive of upper stage and optional service prices) should have been and should be in each year, from 1983-1988, assuming all of the factors discussed earlier and discussed below. Other sets of assumptions will produce slightly different numbers, but the general picture, I predict, will remain the same: it will cost on average more than $250 Million to conduct each Shuttle launch during the remainder of the 1980's. We should be charging roughly that amount, the sooner the better, and not NASA's $50 Million - $71 Million figures. And until we raise Shuttle prices to at least $200 Million, every time a Shuttle is launched carrying primarily commercial consats, approximately $100 Million of taxpayer money has just been unnecessarily wasted, and the incentive to develop more cost effective private space transportation has been unfairly and disastrously reduced, to the long run detriment of this country's economic leadership in space.

Q6: One of your cost categories -- "Advanced Shuttle Transportation" -- is actually referred to in NASA's budget as simply "Advanced Programs." It includes the costs of developing advanced astronaut EVA techniques and early designs for the Space Station and unmanned platforms. Should these costs really be assessed against commercial users as a cost of riding on the Space Shuttle?

A6: This criticism is substantially correct; however, as Exhibit 1 shows, the difference is completely insignificant. The account in question, part of the overall "Space Transportation Capability Development" R&D budget, does indeed include costs from other sub-categories besides "Advanced Transportation Systems." Instead of including the entire $15 Million per year total, I should have included perhaps (I am guessing here) only $3 Million per year total.

Q7: Can you appreciate the fact that the cost of integrating complex government payloads such as Space Lab into the Space Shuttle is substantially more expensive than it is for domestic communications satellites? Then why do you use these costs (included in the "Payload Operations and Support Equipment" part of the R&D budget) in calculating the average fees that should be charged commercial customers?

A7: This criticism also is substantially correct, and also has no significant impact on my numbers or conclusions. I had thought I was excluding Spacelab costs, since I excluded completely the budget account labeled "Spacelab." As a further adjustment, the attached revised exhibits have excluded an additional $30 Million, half of the costs included in this account, as being attributable to purely non-commercial payload integration requirements. Entirely eliminating the account would still not make a significant difference (see Exhibit 1).

A more significant assumption on my part was allocating 15% of the space tracking and data systems costs ($795 Million in 1985) to Shuttle. I could not discern from the materials available to me whether this number is too high or too low; I placed it in my numbers to make the issue addressable. Since no criticism was directed at me regarding this assumption, I can only assume that my 15% allocation is reasonable, and thus have left this estimate in my revised table. Taking it out entirely would have a modest impact on my numbers, equivalent to $6 Million per Shuttle launched in 1988.

Q9: Are you aware that the reimbursable operating cost figures that you used in your analysis contain flight hardware for Vandenberg launches? Therefore, when you divide by only the number of KSC launches, wouldn't this figure overstate the cost of those launches?

Q4: Are you aware that, because of the lead times involved, most of the hardware expenditures in any given budget year are for hardware that will actually fly in subsequent years? Since the flight rate is rapidly going up, wouldn't your practice of dividing the cost of next year's hardware by this year's flight rate greatly overstate the unit cost of the hardware?

Q5: NASA has told us that the total delivered cost of all of the components that go together to make up a Space Shuttle flight (including maintenance on the Orbiter and its engines) is around $50 Million. How do you explain the difference in this number and your estimate of operating costs?

A4 & A9: Either flight hardware actually costs $50 Million per launch, or it costs more than that figure. If it costs more than $50 Million, then NASA is underpricing the Shuttle even according to its own (inappropriate) pricing methodology. If, on the other hand, flight hardware indeed costs only $50 Million per launch, then adjusting my figures to account for Vandenberg and ramp-up effects will not significantly alter my conclusions.

The number of Vandenberg launches is quite small during the time period under discussion; my understanding is that there will be no Vandenburg launches before 1986, and that the number of Vandenberg launches per year during 1986-1988 will be 3 in 1986, 1 in 1987, and 4 in 1988. I am deducting $50 Million per launch from the total operating cost figures shown in Exhibit 1, starting in 1985 (when most of the 1986 Vandenberg hardware is presumably budgeted).

I am adjusting for the KSC ramp up effect by deducting, at $50 Million per launch, flight hardware costs attributable to launches which will occur in the following year, and adding back only flight hardware costs attributable to the current year (see Exhibit 1).

One effect of these adjustments is to make "Total Operations Cost" also an accrual concept, rather than a cash concept; this fits with the reconceptualization of "Total Ongoing" costs from cash basis to accrual basis.

Q5: My reasons for rejecting the $50 Million number as an appropriate estimate of operations costs per launch are many.

First, as I stated in my testimony, I believe it is inappropriate for NASA to claim that all or even most Shuttle-related labor costs are excludable from "Total" operations costs, excludable from estimates of ongoing costs per launch, and fixed in the long run regardless of the number of launches. Labor costs, including both direct and indirect labor costs, are variable for all transportation systems, including space transportation systems. This is precisely the kind of issue which appears to require an audit by independent government accountants; a businesslike accounting and explanation of how much of Shuttle-related labor costs should be viewed as variable in the long run has apparently not yet been presented by NASA in defense of its proposed pricing policy.

Second, I have stated earlier my reservations regarding the idea that Shuttle during the next 5 years is operating at the bottom of a marginal cost curve. Adding a marginal Shuttle launch is not like manufacturing a marginal widget. Shuttle is pressing turnaround time and logistics capabilities, as I understand it, for each of the next 5 years. I fail to see how this is reflected in NASA's "additive" or other cost estimates in any manner whatsoever.

Third, the $50 Million figure appears to have been generated as a part of an attempt to claim that Shuttle "makes money" as long as its prices are above $50 Million, i.e., at $71 Million per launch. However, as I have argued in my testimony, the question is not whether a questionable theoretical argument can be made regarding this $50 Million/launch number, but rather whether use of this number is in fact resulting in a hidden, unnecessary, and uneconomic expansion of the Shuttle program, with resultant long term increases in development costs, labor costs, overhead costs, and other taxpayer subsidized costs. Reliance on average cost estimates such as I am arguing for would reduce the likelihood of unintentionally approving additional unnecessary expenditures.

Much of the argument for the 5th Orbiter, for example, seems to stem from this kind of muddled thinking about cost per launch. If an extra launch on Orbiters 1-4 "costs" only $50 Million, why are we considering spending $2 Billion for another orbiter? Why not fly the old orbiters more often in each year? (Answer: because, as I have argued, due to rising marginal costs per launch, it is currently costing much more than $50 Million to try to obtain an additional launch per year from each of the existing orbiters). The logic of the $50 Million number quickly breaks down from internal contradictions.

Q12: Are you aware that a few years ago private investors offered to finance the production of a fifth orbiter? Why do you think investors would offer to do such a thing if Shuttle prices are as far below operating costs as you contend?

A12: It has been my understanding that the private 5th orbiter proposed to handle marketing of commercial Shuttle launches, possibly on a monopoly basis, but without attempting to pay the average costs of Shuttle launches; instead, only NASA's proposed prices would have been paid. If this is so, then, as I have argued, such a proposal would only have been profitable as a result of receiving large implicit operating subsidies from NASA (NASA would not have charged average costs for the use of facilities, conducting of launch operations, use of R&D improvements, use of facilities improvements, charges for overhead, etc). In the absence of such heavy subsidies, I believe a "private" 5th orbiter proposition must, indeed, prove unprofitable.

Klaus Heiss was the man responsible for the private 5th orbiter proposal. The following quote from page 24 of his 3/15/83 testimony before this committee may suggest what is most likely here: "Without the ongoing procurement of improved orbiters (five and beyond), the direct operations cost for shuttle launches will make the shuttle clearly uncompetitive in world markets: over 12 years, the operations cost per flight will be at least $120 million (1983 dollars, or $57 million 1975 dollars). With the reduced flight level implied by a four-orbiter fleet - say 23 flights in 1989 - the cost per flight may substantially exceed even this number." Note that, as shown in Exhibit 3, the "Total" operating cost per launch figure implied by NASA's current numbers for 1988, in 1983 Dollars, is only $93 Million per launch, which is 25% below the $120 Million figure Mr. Heiss was estimating in March of last year. Exhibit 4 shows the same numbers, as well as my alternate estimates, in real year dollars.

Q14: In your testimony, you compare the costs of launching payloads to geostationary orbit by Ariane vis-a-vis Shuttle and conclude that Ariane now and in the future will offer cost advantages.

a) Don't you think that the current subsidy for Ariane itself may obscure such comparisons?
b) Why don't you think it is reasonable to attempt to achieve high load factors on the Shuttle with communications satellites? Would it be preferable to have low load factors and additional ELV launches?

A14a: In my testimony I directly addressed the issue of Ariane subsidies: "I know of no publicly available comprehensive analysis of Ariane's costs. However, Arianespace is a separate organization from ESA, has shareholders, and claims to be able to make a profit at current prices. It is definitely subsidized in terms of R&D, but it may not be more than moderately subsidized otherwise... Even if ESA & CNES are moderately subsidizing Ariane operations right now, as I suspect they are, I also suspect that, due to the Ariane moving down its own experience curve (which is probably steeper than Shuttle's) the $50 Million/launch price will cover average cost of Ariane operations within 5 years, and possibly even produce a small profit."

Although Ariane subsidies (as well as Shuttle subsidies) certainly do obscure comparisons, that should not discourage us from attempting to make reasonable estimates based on the best information available. If Shuttle is clearly

economically superior to Ariane in terms of cost for satellite launches, I am surprised that NASA has not yet produced a careful analysis proving the fact publicly. Comparisons of Shuttle prices and Ariane prices are what is obscuring the issues here, not attempts to estimate and compare present and likely future costs of these two vehicles.

However, if it did turn out that Ariane is heavily subsidized, that would be a serious matter, equivalent to what is usually called "dumping." This would mean that Arianespace is unfairly competing with General Dynamics Convapace, and Transpace Carriers, Inc. They might have a valid case against Arianespace. Until such a case could be proven, or until the Europeans chose to reduce such subsidies as may exist, and to raise Ariane prices to reflect its costs (perhaps following Shuttle's lead), private for-profit American competitors might have to work especially hard and intelligently to prosper in the face of unfair competition from foreign shores. But even if such unfair foreign competition does exist, and even if it might continue to exist for some years to come, I believe American private space transportation companies can indeed successfully compete for business, especially for American business, assuming at least the absence of additional unfair competition from NASA. Instead, NASA's proposed Shuttle pricing policies make it even harder for private firms to finance and develop effective commercial American competition to Arianespace. To put it bluntly, responding to the possibility of Europeans dumping on American industry by allowing NASA also to do so is not the best way to encourage the development of entrepreneurial American space transportation companies. Raising Shuttle prices now, and putting pressure on ESA to end as soon as possible any subsidies which may exist to Arianespace would both be steps in the right direction.

A14b: This question, regarding Load Factors, has two possible interpretations. I will address both of them.

The first interpretation involves the question of launching almost-full Shuttles. My main concerns are with NASA's methods for estimating the cost of a full Shuttle launch and with its pricing policies, not with methods NASA might reasonably use to fill up a launch now and then which is already 90% loaded with manned, military, or research payloads. However, even a cursory glance at the NASA manifest shows the large number of Shuttle launches currently manifested whose sole or primary purpose appears to be launching commercial satellites, and not performing scientific or military research or other manned missions. "Load factor" arguments in such cases drive in exactly the reverse direction from what the question suggests: it is more accurate to talk about commercial customers as the reason for such launches, and research customers as being used merely to increase load factors. Using NASA's pricing logic (which I am not recommending), commercial customers should then be charged more than average costs, since the other customers are only "additive."

Even for missions which are in fact, primarily research, NASA should not be allowed to price Shuttle capacity below average costs. NASA, as an enterprising research agency, ought to be managing its activities so as to at all times have a backload of important experimental payloads ready to fly on a moment's notice on a "space available" basis. I therefore cannot see any justification for giving special price breaks for launching commercial

satellites at less than their share of average ongoing costs, even to fill up an otherwise almost full Shuttle.

The second interpretation of this question, which is the one I think was intended, is using the term "load factor" in a non-standard way, to refer to the number of Shuttle launches per year, and not to how full each Shuttle is when launched. I will assume that what is meant by "low load factors" is low number of Shuttle launches per year. I will assume that what is meant by "additional ELV launches" is launches on ELVs of satellites which physically could have been launched on Shuttles in a given year, but were not.

The answer to the question, in this case, is most definitely, "Yes." It is precisely one of the functions of competition to show different players in the market which kinds of uses of their productive capacity are economic. If it costs $100 Million to launch 4 Delta satellites on Deltas, and at least $200 Million to launch the same 4 satellites on a Shuttle, absolutely, the Shuttle should be left on the pad. Why cause wear and tear on a C-5A when the same economic function can be carried out by a Boeing 707 at lower expense, and no additional cost to the taxpayer?

As recently as the 1940's, the twin ideas of marginal cost pricing and load factor maximization had widespread support among American economists, and were used as a basis for arguments to nationalize all major industries. Essentially, the notion was that, "Since private companies cannot survive with prices below average costs, and since it appears to be more 'efficient' to set prices at marginal cost, and thereby achieve higher average load factors than is possible under a regime of 'wasteful' competition, governments should run industries, charge marginal costs, and pay the average loss out of taxes." It was a plausible argument.

Similar arguments to expand the "efficiency of use" of government-owned systems via marginal cost pricing and taxpayer subsidization of losses, resulting in elimination of competition, achievement of an uneconomically high market shares, and concomitant achievement of very high facility utilization rates are still widely made today on behalf of government-owned businesses throughout the world, especially in European countries, Third World countries, and, of course, Eastern Bloc countries, where the argument is not even open to question.

In the West however, and especially in America over the last 40 years, there has been substantial progress in our understanding of how attempting to centrally plan and set prices for an industry so as to promote maximum efficiency of use today inevitably leads to sacrificing technological and economic efficiency tomorrow.

The job of competitive markets is not to maximize "load factors" or any other technological measure of merit or efficiency; the job of competitive markets and competing firms is to promote <u>long run</u> economic efficiency. Due to a lack of adequate accounting numbers, and a resultant tendency to confusion, Government officials and analysts easily fall prey to attempting to improve performance of a government owned business by keeping prices low in order to increase load factors, acting as if it was possible to reverse the normal pattern of cause and effect here: the cause of a high load factor in business is the ability to provide service at low cost, which in turn enables charging

a low price; the low price then, in turn, creates the high load factor. It does not work the other way around. Artificially encouraging a high load factor with an artificially lowered price, when the price is below average cost, in no way serves to promote economic efficiency. Instead, it promotes economic waste. In particular, it promotes perpetuation of waste: since incentives to develop lower average cost competing methods of service are suppressed by the artificially low prices, more economically efficient technologies are not developed. The old, high average cost technologies remain in use, and remain apparent "state of the art" much longer than would otherwise have been the case.

If IBM's competition had been suppressed by similar pricing methods to Shuttle's, with losses made up at taxpayer expense, and if IBM had been allowed to thereby force all computer users to use IBM-360s, in order to increase the efficiency of utilization of IBM computers, indeed, IBM 360 utilization and load factors would have gone up. For a while. But in the longer run, neither minicomputers nor microcomputers would ever have been developed...in America.

REVISION 3/6/84

AN ANALYSIS OF SHUTTLE COST & PRICE PROJECTIONS
All amounts in Millions of Real Year Dollars except where marked.
All numbers rough.

Exhibit 1:		81+82	1983	1984	1985	1986	1987	1988	
LAUNCHES:	#KSC/YR	4	4	8	11	13	20	20	
	#VDB/YR					3	1	4	
ONGOING SHUTTLE COSTS:			Feb 84 Budgeted			Analysis based on NASA Feb84 data			
"OPERATIONS:"									
	Budgeted SSH "Oper" cost	1338	1402	1339		1250	1175	1200	note1
	Plus: Reimbursed OpCosts	312	264	665		1000	1625	1500	note1
	Less: Next Yr Vanden Hdw	0	0	-150		-50	-200	-200	note2
	Less: Next Yr KSC Hardwr	-400	-550	-650		-1000	-1000	-1000	note3
	Plus: This Yr KSC Hardwr	200	400	550		650	1000	1000	note3
	TOT KSC SSH "OP" COSTS ?	1450	1516	1754		1850	2600	2500	note1
OTHER LONG RUN VARIABLE SSH COSTS:									
	Engr & Techn Base	70	93	105		105	105	105	note4
	Payload Oper & Supp Equi	22	26	30		30	30	30	note4
	Advanced Programs-Transp	3	3	3		3	3	3	note4
	SpaceRes&Techn Base--SSh	24	24	26		26	26	26	note4
	15% ? of SpaceTrack&Data	72	101	119		119	119	119	note4
	Orbiter Use Costs	60	120	165		195	300	300	note5
	Orbiter Spares	115	202	332		332	332	332	note5
	Program Management	419	440	473		480	486	493	note4
	TOT OTHER LRUN VAR SSH	785	1009	1253		1290	1401	1408	
AMORTIZED INVESTMENTS:									
	Capability Development	1725	1649	1465		1200	825	421	note5
	Less: Orbiter+OrbSpares	-843	-667	-558		-332	-332	-332	note5
	Plus: Construction	25	61	31		15	15	15	note4
	Total to Amort-Next10yrs	907	1043	938		883	508	104	
	TOT CURRENT AMORT INVEST	91	195	289		377	428	438	
TOTAL SHUTTLE ONGOING COSTS		2326	2720	3296		3517	4429	4346	

Exhibit 2:
"TOTAL" SHUTTLE COST LOOKS LOWER THE MORE COSTS YOU EXCLUDE:
(All #s calculated using same Feb84#s, above:)

TOTAL "FULL" costs(incl sunk)	3176	3570	4146	4367	5279	5196
TOTAL "CASH" costs	4010	4063	4106	4178	4209	3712
TOTAL "ONGOING" costs	2326	2720	3296	3517	4429	4346
TOTAL "TOT OPER" cost-NASA def	1450	1516	1754	1850	2600	2500
TOTAL "OUT OF POCKET OPER"cost	1005	1044	1229	1323	1941	1866
TOTAL "ADDITIVE OPER" cost	200	400	550	650	1000	1000

Exhibit 3:	1983	1984	1985	1986	1987	1988
ALTERNATE ESTIMATES--Assume Per Launch OpCosts only fall 65% over next 5 yrs.						
LAUNCHES: #KSC/YR 4	4	8	11	13	20	20
TOT OP COST--NASA FEB84#s,ry$	1450	1516	1754	1850	2600	2500
ALT ESTIMATE--TOT OP COST,ry$	1450	1668	1982	2313	3466	3333
TOT ONGOING COST--NASA FEB84#s	2326	2720	3296	3517	4429	4346
ALT ESTIMATE--TOT ONGOING COST	2326	2872	3524	3980	5295	5179
(ALT ONGOING = ALT OPER + LRUN VAR + AMORT INV)						

RATIONALE: Compare these two OpCost projections, in constant 1983$, below.
If Total OpCosts in 1983 were 1450 for 4 launches,
NASA's projections imply that total OpCosts will rise only 30%,
from 1450 to 1868, when volume rises 400% over the same period.
My estimate is that total OpCosts will instead rise at least 70%,
from 1450 to 2490, if volume rises 400% over this period.
My assumption here is that NASA's per launch OpCosts will indeed fall quickly, just not quite as quickly as NASA has been assuming.
I assume per launch OpCosts only fall 65% in 5 years, not 75%.
Serious cost overruns or schedule slips would result in much higher increases over NASA's estimates of per launch OpCosts.

Inflation divisor, 6%:	1.00	1.06	1.12	1.19	1.26	1.34
TOT OP COST--NASA FEB84#s,83$:	1450	1430	1561	1553	2059	1868
ADJUSTMENT FACTOR:	0.00	0.10	0.13	0.25	0.33	0.33
ALT OPER = OPER * (1+ADJUST FACTOR)						
ALT EST--TOT OP COST, 83$:	1450	1573	1764	1942	2745	2490
PER LAUNCH OP COST,NASA, 83$:	363	179	142	119	103	93
PER LAUNCH OP COST, ALT, 83$:	363	197	160	149	137	125

Exhibit 4:
COST PER LAUNCH--COMPARISON OF DIFFERENT ESTIMATES (REAL YEAR $):

NASA Feb84 #s: OPER, RY$	363	190	159	142	130	125
NASA Feb84 #s: OTHR LRUN VARY	196	126	114	99	70	70
NASA Feb84 #s: AMORT INV, RY$	23	24	26	29	21	22
NASA Feb84 #s: ONGOING, RY$	581	340	300	271	221	217
ALTernate estimate of OPER,RY$	363	208	180	178	173	167
NASA Feb84 #s: OTHR LRUN VARY	196	126	114	99	70	70
NASA Feb84 #s: AMORT INV, RY$	23	24	26	29	21	22
ALTernate estimate of ONGOING	581	359	320	306	265	259

COST PER LAUNCH--DIFFERENT YEAR DOLLARS & DIFFERENT COST CONCEPTS:

NASA Jan82 #s: TOT OP COST,75$	155	96	74	62	56	50
NASA Jan82 #s: OUT OF POCK,75$	108	66	52	55	42	37
(OUT OF POCK OP COST = TOT OP COST - OPER LABOR)						
NASA Jan82 #s: OPER, RY$:	329	215	177	158	150	142
NASA Jan82 #s: OUT OF POCK,RY$	228	148	124	113	112	106
NASA Feb84: "ADDITIVE COST":	50	50	50	50	50	50
Contrast with ALT FULL COST:	794	465	398	372	307	301
(includes sunk R&D costs)						

Exhibit 5:	1983	1984	1985	1986	1987	1988
BUSINESSLIKE PRICE FOR SPACE SHUTTLE LAUNCHES (AVERAGE COST BASIS):						
ALT estim of ONGOING COST, 83$	581	339	285	257	210	193
ALT estim of ONGOING COST, RY$	581	359	320	306	265	259
AVERAGE COST OVER 3 YEAR PERIOD (1986-1988) FOR 53 LAUNCHES:						
273 Million Dollars assuming Alt OpCost estim, RY$ (note contrast with prices, below)	273	273	273			
MARGINAL COST PER LAUNCH:						
ESTIMATED MARGINAL COST, 83$:	309	198	181	168	153	140
ESTIMATED MARGINAL COST, RY$:	309	210	203	200	193	187
MARG = (TOT ALT OPER + TOT LRUN VAR - $1BILLION)/# OF LAUNCHES (Note contrast with prices, below)						
NASA PRICE PER LAUNCH:	.....PHASE 1...			.....PHASE 2...		
In 1975 dollars:	18	18	18	38	38	38
In 1982 dollars:	38	38	38	71	71	71
In RY (Real Yr) dollars:	40	42	45	89	95	100
INCREASE PER LAUNCH IN FEDERAL BUDGET GIVEN NASA'S PRICING POLICY:						
ALT ONGOING - PRICE, RY$	541	317	275	217	170	159
MARG COST - PRICE, RY$:	269	168	158	111	98	87
TOTAL WASTE (UNNECESSARY INCREASE) IN FEDERAL BUDGET GIVEN NASA PRICING:						
# of Commercial Shuttles	1.66	2.00	2.66	4.50	6.75	5.25
# of ComShut * (MCOST -PRICE)	446	335	421	500	664	457

Exhibit 6:	Pre-83	1983	1984	1985	1986	1987	1988
SUNK COSTS--R&D, CONSTRUCTION, AND EARLY OPERATIONS:							
R&D:	10000 ?						
amort over 20 yrs		500	500	500	500	500	500
CONSTRUCTION:	2000 ?						
amort over 20 yrs		100	100	100	100	100	100
EARLY OPERATIONS:	5000 ?						
amort over 20 yrs		250	250	250	250	250	250
TOTAL SUNK COSTS:	17000	850	850	850	850	850	850

NOTES TO EXHIBITS:
All numbers shown for 1983 - 1985 are directly based on numbers from NASA's 1983-1985 budget request.

1. NASA-generated numbers for 1988 include a reference to a "Total" Operations Cost of $2.7 Billion, which consists of $1.5 Billion of reimbursements, and $1.2 Billion of budgeted expense. I also understand that NASA's current expectation is that the budgeted expense line item will be $1250 in 1986 and $1175 in 1987. I have had to interpolate reimbursements for 1986 and 1987. I assumed that since the number of launches was identical in 1987 and 1988, total OpCosts for 1987 would be approximately $2.8 Billion, since 1988 costs will presumably be slightly lower due to continuing experience curve effects. The $1.0 Billion in reimbursements shown for 1986 is an interpolation between $665 and $1625, based on comparing the Shuttle manifest for 1985, 1986, and 1987. Even large changes in this estimate would not significantly affect my conclusions. Note that the $2.7 Billion and $2.8 Billion figures are prior to adjustments for Vandenberg hardware and ramp-up effects (see next two notes).

2. Rationale for my adjustment to account for Vandenberg launch hardware costs included in the NASA budgets are described in my answer to Question 9.

3. Rationale for my adjustment to account for "ramp-up" effects (hardware budgeted in years prior to actual launch) is described in my answer to Question 4.

4. The Program Management numbers for 1986-1988 are NASA numbers. I have extrapolated the other accounts as flat from 1985 through 1988 (which means, declining, in constant dollar terms). I do not know whether NASA's current expectation is that they will rise or fall. Assuming that, on average, they are expected to stay flat, then any cost overruns on these numbers would raise average Shuttle launch costs.

5. I have treated orbiter spares as an ongoing expense, deducting them from "Total Capability Development" costs, and adding them to "Long Run Variable Space Shuttle Costs". I have extrapolated them on a flat basis from 1985 - 1988, which means falling in constant dollar terms. It is my understanding that this is a potential area for major cost overruns. I have also deducted from the "Total Capability Development" cost category budgeted orbiter construction costs shown in the NASA 1985 budgets during the years 1983-1985. The remainder is then amortized. I have assumed that there are no further orbiter construction costs in the NASA numbers regarding "Total Capability Development" costs after 1985; hence from 1986 on, I subtract only the $332 Million Orbiter Spares cost from Total Capability Development Costs to arrive at the amount to amortize over the the following 10 years. (Shuttle-related R&D and value-engineering investments in 1986 are thus still being amortized in 1995, year 24 of the Shuttle program).

I have picked a valuation of $1.5 Billion per orbiter for assessing Orbiter Use Costs. Original Cost of an orbiter is apparently about $1 Billion. Replacement cost of an orbiter is apparently about $2 Billion. I have assumed the orbiter's intended life of 100 launches per orbiter. This results in a cost per orbiter use of $15 Million. Assumption of a shorter useful life, or introduction of probabilities regarding full or partial loss of an orbiter, would result in higher numbers than $15 Million Orbiter Use Cost per launch.

Mr. VOLKMER. Thank you very much, Mr. Salin. I now recognize the gentleman from New Mexico, Mr. Lujan.

Mr. LUJAN. Thank you very much, Mr. Chairman.

You make some awfully good points. I agree with you that we ought to move into the whole commercialization of vehicles as soon as we can. As a matter of fact, if I thought that Pan American or TWA or Eastern or Continental or whoever could come to NASA and say, we will operate the rides back and forth into space for you, I would immediately vote for such a thing.

There is one concern, however—let me also say before I voice my concern that the whole question of shuttle pricing has an awful lot to do with whether the commercial ELV companies can get into business, and as long as NASA keeps the price down, it is not going to encourage the private ELV companies.

But the other side of that is that an awful lot of good research goes on, even if we take your $300 million per launch figure. I am not sure that we can just discount that. Maybe it is worth the $300 million just for the research and reducing the cost a little bit by making some charge to private companies for putting in their satellites or whatever we are going to do for them.

It is a complex question that I am not sure which side I want to jump on very quickly. I am on both sides, I guess. I am riding the two horses and moving on ahead with it.

I did want to ask you if we take your $300 million figure for a launch, the shuttle carrying 65,000 compared to Delta carrying 2,800—that is 4 percent.

Mr. SALIN. Excuse me, the 2,800 is for transfer orbit. The Delta does about 7,000 pounds, I believe, to low Earth orbit, which would be the comparable number to the 65,000-pound number.

Mr. LUJAN. That is even 1½, not quite 1½ percent, 1 percent.

Mr. SALIN. No, it is 10 percent. Delta can do about 10 percent of a shuttle.

Mr. LUJAN. Oh, 7,000, I am sorry—10 percent.

Mr. SALIN. Yes.

Mr. LUJAN. That would mean that in comparable cost per launching on the shuttle would be $30 million for a Delta.

Mr. SALIN. That is right, which is the current price of a Delta. Now, if the shuttle did not have what I believe are clear, inherent, economic, what are called technically diseconomies of scale—you see, on a Delta, you have got one payload per mission. If the shuttle was able to efficiently use all 65,000 pounds, you are entirely correct. Even at $300 million per launch, the shuttle would be competitive with Delta.

The problem is you can't get 10 satellites in the Delta [1] right now. You can get three Delta class satellites right now; it will soon be four. I agree with your earlier point that it is really 4.5 or 5 as you go to PAM-D2's, but it is not 10. So, that is part of the problem.

Mr. LUJAN. Yes. Well, I think you make some very good points, and that is something that we have to keep in mind all the time. On the one hand, you don't want to compete with the private

[1] The witness intended to say "shuttle" not "Delta."

launchers, but on the other hand, you want to continue the forward progress of the shuttle.

Mr. SALIN. I entirely agree, if I may address a few of your points. As I see it, if the situation is at all along the lines of what I have tried to present as clearly as I had the wit to do so here, it is not against the shuttle. It says the shuttle should be used for what it is best at rather than for things that it is not just poor at, but unsupportable at. The kinds of things that it is best at are supporting the research and manned missions. So, for example, even those aspects of commercially related research which require manned work, are not necessarily——

Mr. LUJAN. I guess what you are saying really, and I understand, is that while we are having 24 launches because we are including both commercial and the research and whatever else is in there——

Mr. SALIN. Right.

Mr. LUJAN. Get out of the commercial business, do your Government business, and maybe you can do that with 10 launches rather than 24.

Mr. SALIN. Yes, although it is not even so strong as "get out of the commercial business." It is to raise the prices to approximately where the costs are. Do what is necessary to encourage the kinds of commercial things that can only be done on shuttle, but not, via the shuttle pricing policy to distort the entire marketplace, not just for a year, but in terms of the whole development of the 1980's of what could happen in the commercial marketplace.

Mr. LUJAN. What about NASA refusing to handle those commercial aspects that can be done by the ELV's?

Mr. SALIN. I think that would be going exactly too far. In other words, I think that provided that there is some business that——

Mr. LUJAN. Only those that can be done by the ELV's I am saying. I don't say all commercial ventures.

Mr. SALIN. Let me turn it around. If a businesslike accounting of the shuttle costs comes up with the number, the customers, private companies, for whatever reason are still willing to pay for, then I see no reason why private companies should not be able to use the shuttle.

Mr. LUJAN. You might want to do some—some private companies might want to do some research, at least in my view, if McDonnell Douglas and Johnson & Johnson want to conduct some research, there is nothing wrong in the Federal Government saying, we are going to kick in half the cost by only charging you half of what the cost is.

Mr. SALIN. I think that if such things are clearly part of the NASA budget, and if part of NASA's allocation, in effect, is explicitly a subsidy of $200 million for some research that NASA, in its expertise, says is worth doing, then if the other half can be put up by a private company, yes. I see no objection to that at all.

Mr. LUJAN. You make some very good points, and that is a concern that we have. On the one hand, we want to encourage the private sector. That goes without saying. I think everybody on the committee agrees with that.

OK. That is a tough one to resolve. Thank you.

Thank you, Mr. Chairman.

Mr. VOLKMER. The gentleman from Virginia, Mr. Bateman.

Mr. BATEMAN. I am intrigued with the proposition that there are some things that could best be done, if at all done, on the shuttle as opposed to ELV's. Have you tried to or been able to get any empirical data on situations where a commercial firm wanting to put a given payload in space has opted for space shuttle when it really wasn't necessary as opposed to an ELV because of an artificially low pricing policy? Do you have any objective or empirical data on that?

Mr. SALIN. I don't want to misinterpret your question. If I understand it, there have been a number of occasions when in different kinds of NASA testimony before this committee, statements have been made to the effect that there is a need to keep the shuttle "price-competitive." Now, what I would assume that this means is that if the price, for any reason, including cost recovery, was higher, that that meant that the judgment of these individuals was that customers, satellite customers, if the price was any higher, would have stuck with the Delta.

I have even seen explicit statements to the effect that NASA felt it had to introduce an extremely low price in order to get people off of the Delta, which is obviously what people were using, so I think the answer is unquestionably "yes." I know of no evidence to the contrary.

Mr. BATEMAN. To this point, aren't we largely talking about if the policy is to make the price competitive, competitive vis-a-vis Ariane.

Mr. SALIN. Excuse me. My understanding of the policy is that it is not to make it "competitive" but to somehow cover costs, cover "out-of-pocket" costs, and the claim is that this price which somehow covers "out-of-pocket" costs is nevertheless competitive. What I am saying is, it certainly doesn't cover costs. I do not believe, it is almost the heart of my testimony, that if shuttle prices were raised to what their actual costs were, no, it would clearly be uncompetitive and, I believe, is completely uncompetitive right now for launching what I call vanilla satellites, ordinary communications satellites.

Did I answer your question?

Mr. BATEMAN. This, of course, assumes that there is another alternative that is in the timeframe that is important and available to us.

Mr. SALIN. Yes. This assumes that Delta and Atlas Centaur are capable of being operated by private companies as they have been in the past under Government contract.

Mr. BATEMAN. That is all I have.

Mr. LUJAN. Excuse me. If the gentleman would yield. Are you saying that you are considering the Ariane as a private firm?

Mr. SALIN. The Ariane is, right now, a quasi-private firm. As I go into a bit in my testimony, it does have definite Government subsidies of certain types, although for operations I am not sure that they are that large. Arianespace, the company which operates the Ariane, is a quasi-private company that has different governmental, and I think, Government-owned and corporate shareholders. So, it is sort of like a Conrail, if you will.

Mr. LUJAN. But it is subsidized.

Mr. SALIN. I believe so. I have been unable to obtain any figures to say how much. Its R&D, like the shuttle, is completely subsidized. It is subsidized by ESA. The operating costs, I believe are subsidized in terms of operation of the Kourou launch site and possibly in terms of the use of—I think it is the ESA mission control centers. The important question is how much are those subsidies, and my suspicion is that they are not necessarily that large. I believe they are nowhere near the order of what is done on the shuttle.

It would not change the substance of my testimony if it were[1] heavily subsidized. The important point here is Delta and Atlas.

Mr. VOLKMER. The gentleman from Pennsylvania.

Mr. WALKER. Thank you, Mr. Chairman.

Do you think it would help at all if we amended the Organic Space Act to basically make a part of NASA's mission that of spinning off commercial activity and make certain that NASA understands that as a part of its mission, it is to be conscious of the commercial activity on the outside and try, insofar as possible, to spin off that which it is doing——

Mr. SALIN. I think that would be an excellent proposal. I am convinced that there are many in NASA who would like to see something like that. My understanding, I may be wrong, but my understanding is that many people in NASA think of NASA as the agency they joined as a research agency, and they want to do research.

Mr. WALKER. I think that that is the case, too, and I think that what we have is more and more of an orientation of NASA moving beyond research and development and going into marketing and some of these kinds of things which Government agencies, just by their very nature, are not necessarily proficient in doing.

Mr. SALIN. Yes, sir. If I may, it is also extremely dangerous, because a Government agency that has the ability to subsidize its services can, of course, engage in wonderful marketing. You just price low enough that everyone has to buy it and the taxpayer pays the difference. It is very dangerous.

Mr. WALKER. Have you looked at the pattern that developed at the time that one of the commercial firms was attempting to buy into the fifth orbiter? Have you looked at whether or not there was a predisposition on the part of NASA to try to prevent that from happening by throwing roadblocks in the way of such a scheme?

Mr. SALIN. I am not personally familiar with the history of the Space Transportation Co. Actually, some of this has been my suspicion for a long time. I only had the chance to go into the numbers in the last few weeks, but for several years I have been of the opinion that the shuttle had this inherently high cost. I didn't pay close attention to the development of the Space Transportation Corp. fifth orbiter proposal.

I will say that I think that many of the bottom line points I am making here were implicit in Klaus Heiss' testimony of a year ago which I have read, not his conclusions regarding pushing for the fifth orbiter, but many of his assumptions regarding the situation.

[1] Instead of "it were" the witness meant to say "Ariane was."

Mr. WALKER. If I understand what you are saying correctly, what your saying is the shuttle is a very unique transportation system with a very unique capacity——

Mr. SALIN. Absolutely.

Mr. WALKER. That has both national security implications, and so on, but also some very, very important commercial applications insofar as we are going to use the space station as a launch pad for commercial activities, the shuttle is absolutly integral to most of those kinds of applications.

Mr. SALIN. Yes.

Mr. WALKER. But that there are also some things the shuttle does just as well in some cases or maybe not as well in the commercial sector. What you want to see here is some kind of delineation of what the Government is subsidizing with regard to shuttle activities.

Mr. SALIN. Yes, and it is not just that. By raising the price closer to cost, it allows the market to differentiate. Rather than having to bureaucratically allocate payloads, which I think would be a nightmare, if the price is raised closer to cost, individual decisionmakers will decide whether to use the shuttle or not. So, if I am RCA and I am launching a vanilla satellite, and the price is too high, I put it on the Delta as I have done for many years. If I am a Sparx or a commercial company like that, I might be able to conceive of some way of getting some value out of a private launcher, but for the foreseeable future, I am going to want to do it on the shuttle.

So, the commercial companies will distinguish themselves what commercial activities to conduct on the shuttle, and which things to conduct on the competition.

Mr. WALKER. Your contention is that the per launch cost of shuttle right now is $300 million?

Mr. Salin. It is very complicated. What I have tried to show in my testimony is that the numbers you come up with for the cost of the shuttle depend very much on how you look at it. The short answer is yes, but what is more important is to understand that looking at shuttle costs from a businesslike perspective, it is on that order. It is $200 to $300 million. It is actually more in earlier years. I am talking about 1987 and 1988.

Mr. WALKER. OK. If that is the real cost of shuttle launch capacity at the present time, what is the subsidy involved at the present time?

Mr. SALIN. Let me distinguish two things. For Government payloads——

Mr. WALKER. Let's talk about commercial payloads. For most Government payloads, commercial activity on the outside is going to be basically backup support rather than primary support, so let's talk about commercial payloads. The commercial customer coming to NASA right now, that might look for some other commercial firm. How much of a subsidy is he getting from NASA right now?

Mr. SALIN. That is the horrible thing. He is not really getting a subsidy at all. The taxpayer is forced to pay for the difference between the cost of the launch of a communications statellite on the shuttle and what the customer pays.

Mr. WALKER. Well, in my terminology, that is a subsidy.

Mr. SALIN. I understand, but the difference is this. Normally, a subsidy means that some value has been received by the customer, but because the customer could buy the same value at the same price he is paying, on a Delta, he is not receiving a subsidy. The taxpayer is paying, but he is not receiving it.

Mr. WALKER. Without engaging in the semantics of what a subsidy is, what I am asking is, how much is NASA propping up the cost of the shuttle launch for commercial customers?

Mr. SALIN. OK. Let's take 1988 where the pricing policy would be approximately $100 million. So, $100 million roughly would be charged for the Shuttle. My attempt to analyze the numbers suggests that the marginal cost of a shuttle launch in that year is at least $150 million, so it is a minimum of $50 million in 1988, more until then.

Since I argue that the pricing policy should not be set at marginal cost, but closer to average cost, and I argue that average cost in that year will be close to $300 million—you can get it down to $200 million pretty easily, but if there are major cost overruns, it would be higher. In that case, the total subsidy is $100 million or $150 million.

I want to make one point here that I have made elsewhere in my written testimony, and it is crucial. Normal thinking by economists about marginal cost is that a marginal cost curve goes like this,[1] so that your marginal cost for each additional launch, let's say, is lower and lower as you go on down. It also is that at some point when you try to get too much out of a system, produce too many units, the cost per unit starts going up again. It is not clear to me that over the next 6 or 7 years, when the shuttle program is working very hard to make the shuttle operational, that when you try to add one more launch into a year, you are not in fact coming up with a much higher marginal cost for that extra launch. You are straining the people, you are straining the system, you are straining the reliability, so it is a very complex issue to decide what the marginal cost of a launch is in any particular year.

What I have tried to estimate is sort of an average marginal cost, if you will. It is sort of a peculiar concept but I think it is valid in this case.

Mr. WALKER. Thank you, Mr. Chairman.

Mr. VOLKMER. I have several questions.

You are estimating, when you say the $300 million per launch or the $250 million per launch, is the $50 million for overruns?

Mr. SALIN. Yes, particularly in the operations, what NASA calls its total "operations" part of the budget.

Mr. VOLKMER. Schedule slips?

Mr. SALIN. Schedule slips—I did not attempt to estimate schedule slips because I didn't have enough information. This is assuming no schedule slips.

Mr. VOLKMER. Just overruns?

Mr. SALIN. Yes; this is overrun given a schedule they posited. Now, what could easily happen instead is that there are schedule slips, which means that they are not actually accomplishing as much in each year, and I believe the total cost would therefore be

[1]During testimony the witness visually indicated a downward sloping curve.

lower in each year if their schedule did slip and if they planned for it.

Mr. VOLKMER. Well, let's assume that we——

Mr. SALIN. But the cost per launch would probably be higher than these numbers.

Mr. VOLKMER. In the 3 years we had 53 launches, and at $50 million per flight, we are talking about over $2.5 billion, just in what you consider overruns.

Mr. SALIN. That is correct.

Mr. VOLKMER. What is your basis for the overruns?

Mr. SALIN. My basis for the overruns is the calculations that are at the bottom of the first page of my exhibits, the numbers. If you look first at NASA's expectation on total shuttle operating costs in 1983, at the top of the page is the number 1,650, and they believe that total operating costs in 1988 will be $2.7 billion, so $1.6 billion going to $2.7 billion. Now, if you look at the top line, that is starting with four launches in 1983, they are going to be building up to doing 20 launches in 1988. That is a 400-percent increase in the number of launches per year.

What I point out at the bottom of the page is that these are attempts to estimate real year dollars, so $1.6 billion in real year dollars, is $2.082 billion in 1988. This means that if NASA wasn't going to make any experience curve improvements, which of course we all believe it will do, the cost of doing 4 launches in 1988 would be $2.082 billion. Now, we all agree that their cost per launch, for experience curve reasons, is going to go down. What I am saying is that whereas they seem to believe that with the number of launches per year going from 4 to 20, their total operations cost budget only needs to go from $2.082 to $2.7 billion, I am claiming it should instead go up roughly 33 percent over that number, which is where I get my $3.599 billion. In other words, I think this is a conservative adjustment to their projections.

Now, I have to say, I don't have elaborate numeric bases for this assumption. I do believe, sir, that if you put six fairly independent analysts on this problem, several of them, I believe, would come up with higher numbers than this.

Mr. VOLKMER. Well, I disagree with your numbers. I also, looking through your analysis and your testimony, do you not also assume that much of the labor costs that are presently there would not be there if you reduce the number of shuttle launches?

Mr. SALIN. This is a very important point. What I believe is that, in the longer run, 5 or 6 years out, labor costs are mostly variable, not all, but mostly. In the short run, they are not. When you have a large staff on hand and you scrub a mission, you are not going to be able to scrub 10 percent of your labor, but what I am claiming is that if you look 5 or 6 years out, if you cut back one or two missions 5 or 6 years out, I claim that that frees up a certain amount of NASA labor, throughout the organization, to work on research and other projects, and my analysis is based on that kind of assumption.

Mr. VOLKMER. In other words, you are assuming then that you can reduce the number of people that you have at Kennedy and at Johnson and at Marshall and at the headquarters out of the shut-

tle operations and put them elsewhere if you just reduce the number of flights per year?

Mr. SALIN. Yes. Now let me make this very clear. I am not saying by what percentage. I am simply saying it is not completely fixed, and I believe that NASA's own costing analysis assumes, for all intents and purposes, that it is all completely fixed. If I may point out——

Mr. VOLKMER. You are assuming, of course, that it varies with the flight numbers.

Mr. SALIN. I am not assuming that it varies directly with the flight numbers.

Mr. VOLKMER. But you are assuming that it does vary to some extent.

Mr. SALIN. I am assuming that management is able to—the answer is yes. The question of how that comes about is more complex. It has to do with the planning process over a period of 4 or 5 years.

Mr. VOLKMER. Did you also analyze, let's put it this way—I think if you really would sit down and learn the total operation, how it operates, I think you may learn that many of those are fixed no matter how many shuttles. In other words, if you have one shuttle operation, you are still going to have a fixed number. That number would stay basically, if you had one or five.

Mr. SALIN. I agree there is such a number. What I am disputing is that in 1988, we have got a total shuttle ongoing cost of $4 billion, total operations cost by NASA's numbers of $2.7 and by mine, $3.6. I believe mine are more realistic, so let's take the $3.6 billion.

Mr. VOLKMER. Well, I disagree.

Mr. SALIN. I understand.

Mr. VOLKMER. And only time will tell.

Mr. SALIN. I understand that, too. However, what I am saying is that out of that $3.6 billion, or even $2.7 billion, the question is what is the cost to NASA of doing one launch in 1988?

Mr. VOLKMER. In the costs that you have in the period of 1986 through 1988 in the operations, operation costs and reimbursement costs in that area, how much did you take out of the NASA part of the budget when you analyzed the budget, for Vandenberg operations?

Mr. SALIN. I did not include any costs from Vandenberg operations.

Mr. VOLKMER. Well, how much did you take out?

Mr. SALIN. I am not sure I understand.

Mr. VOLKMER. You had to take something out in the operations cost of what NASA had in their budget item because you have Vandenberg in there.

Mr. SALIN. I am sorry. I am not sure I understood your question. You are saying that the operations cost numbers for 1983, 1984, 1985 in the NASA——

Mr. VOLKMER. And 1986, 1987, 1988 in your operations cost and your reimbursable costs, how much did you take out of the NASA figures for Vandenberg?

Mr. SALIN. I did not take anything out of that nature, if I understand the question properly.

Mr. VOLKMER. But there is Vandenberg in there.

Mr. SALIN. Let me make sure I understand this. If Vandenberg is in there, this would say that NASA is projecting, then, that in 1988 to do 20 launches out of Kennedy, its total operations cost would be less than $2.7 billion, that its number of launches is going to increase by 400 percent and yet its total operations cost is essentially going to remain flat, in real terms?

Mr. VOLKMER. Well, it is not really flat, but approximately, yes.

Mr. SALIN. Well, you only have to go down to $2.1 billion for it to be flat. I guess I would have to say that clearly I don't have special access to the numbers. I find that very hard to—I wouldn't bet money based on that, I guess is what I am saying.

Mr. VOLKMER. OK. And also, by including Vandenberg costs in your totals, if you even extrapolate it, add the 33.3 or anything, it throws yours off also, does it not?

Mr. SALIN. Yes, it does. I do believe, if I have any understanding of the numbers as you are talking about it, that that would not change any of my major findings,[1] but I have to say that is an important point.

Mr. VOLKMER. The other thing that—how do you arrive at the figure that $20 billion would be added to the Federal budget in the next 5 years or are we saying you are going to save $20 billion?

Mr. SALIN. No, that is very important and it is an ambiguity in my text. I am not saying that that $20 billion can be saved. With the Shuttle program operated, and it should be operated, you cannot save that amount of money. What I am saying is that a portion of that $20 billion, the part that is, in effect, wasted subsidy, that I was talking about earlier, the part that is unnecessary costs of launching satellites that could easily be launched otherwise, that is the part that can be saved.

My estimate of those total amounts is at the bottom of page 2 of my exhibits, second page of numbers, where I take the number of commercial shuttle launches estimated essentially assuming three Deltas per shuttle in the first 3 years and four Deltas per shuttle in the next 3 years. I am only dealing with PAM-D1 and PAM-D2 class payloads, by the way. I say that the total unnecessary increase is somewhere between the bottom line and the upper line. In other words, roughly somewhere between three-quarters of a billion dollars and a billion dollars a year over the next 5 years.

I want to emphasize that this kind of thinking tends to hold more true for longer planning horizons, in other words, 1986, 1987, 1988.

Mr. VOLKMER. In other words, you are saying basically, you take the $300 million cost on your estimate minus the $71 million, plus the number of commercial flights and that is approximately what you would end up with.

Mr. SALIN. Yes, but I want to point out that I am not using $300 million. If you look on the 1986, 1987, and 1988, that is a rough average number overall, the precise numbers I am using range—this is over on the right—292, 161, 143. If you are on a more or less average cost basis, then it is $292 million cost in 1986 per launch, $168, and $143.

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[1] See "Replies to Questions."

If you are using a rough marginal cost pricing, it is a cost of $215, a cost of $118, a cost of—I am sorry—that is the difference. These are not costs. This is cost minus price. If you will, that is a measure of the unnecessary subsidy, and for these launches, it is unnecessary.

You multiply that difference by the number of launches down below and you get the totals. So, for example, 5.25 times 93 is $486 million. Is that clear?

Mr. VOLKMER. Now, you quite agree, I guess, that we would still have to have the shuttle and the shuttle operations even if we carried no commercial?

Mr. SALIN. Absolutely, no question about it.

Mr. VOLKMER. And that those ongoing costs attributed to that would remain with the Federal taxpayer?

Mr. SALIN. I am not sure I understand your question, sir.

Mr. VOLKMER. Let's say we have got four shuttles, and we have the operations on costs on those whether they fly one time each year, twice a year, or six times a year. You still have nonvariable costs.

Mr. SALIN. There is no question there is some invariable cost. The question is how much.

Mr. VOLKMER. But those costs would remain even if we never flew a commercial flight?

Mr. SALIN. Yes, sir. The basic principle which I want to emphasize again is that the amount of your costs that are fixed is less the longer term you are planning. In other words, costs that are completely fixed this year, are largely fixed next year, mostly fixed the year after that, become increasingly variable as you go year by year. I believe this is a very well established principle in economics and in business.

Mr. VOLKMER. I disagree with you. I think that if you would analyze it a little more, I think you will find that many of those costs will continue on no matter how many flights you have.

Mr. SALIN. Some of them I have no question will as long as there is a program. The necessary question is how much, and I have no way of estimating that.

Mr. VOLKMER. And the same thing I would like to ask you when you get into the ELV's, whether it is the Delta, Atlas Centaur, or Titan, or anything else, how much when you figure the cost of those, how much should the Government be able to recoup, the taxpayers be able to recoup, for the R&D and the tooling and all that went into the development of those?

Mr. SALIN. That is a difficult question. I would say that if the Government was prepared to recoup the same cost for the shuttle, I would have no problem with their recouping those costs for the Delta and Atlas Centaur. But, I think it is impractical in many different ways. Those costs are sunk, just as the costs we have already sunk in the shuttle are sunk, and I think it is perfectly fine public policy to put up say, for bid, the Delta facilities and the right to operate the Delta. If you put it up for bid, then what that means is the market, at a point in time, is asked "what is it all worth? Buy it and then it is yours." That seems to me the most reasonable way to recoup those R&D costs.

Mr. VOLKMER. In other words, we wouldn't recoup them, really.

Mr. SALIN. Well, we would not necessarily recoup the amount paid into it, but we would certainly recoup their value. If there were three private firms bidding for the Delta, one of them thinks that the rights to the Delta are worth $25 million, another thinks they are worth $50 million, another thinks they are worth $75 million, and they are all qualified firms, then in the bidding contest, one of them would pay $75 million to the Government. That is as good a way as it is really possible, practically, to get an estimate of what those rights are worth.

Mr. VOLKMER. But, aren't the rights to the Delta or the Atlas governed again by the business sector in competition with the Ariane, not what was sunk into it. In other words, if you take 1982 or 1983 dollars, and say that everything that was sunk into the Delta the today would probably run close to maybe $1 billion.

Mr. SALIN. I don't know the number, OK.

Mr. VOLKMER. Whatever it is. That has nothing to do with what a businessman is going to pay for it.

Mr. SALIN. That is correct.

Mr. VOLKMER. He is going to pay for it what he thinks that he can pay and amortize that off over a period of time on the number of Deltas he can sell in competition with the Ariane.

Mr. SALIN. Correct, yes.

Mr. VOLKMER. If we take the shuttle out of it and we have got the Ariane in it.

Mr. SALIN. Yes.

Mr. VOLKMER. Right now, the Delta costs more than the Ariane.

Mr. SALIN. That is perhaps true right now. I don't have detailed in the sense of engineering cost numbers or expectations of what, say, Transpace Carriers thinks it will be able to do Delta launches for—I suspect it is on the order of $30 million—and make a profit. The important question here is how much value engineering can be done in future on the Delta. In other words, can Delta drop its costs at least as quickly as Ariane will be able to drop its costs?

Mr. VOLKMER. When you determine your cost of the shuttle on one page where you use other shuttle-related costs?

Mr. SALIN. Yes.

Mr. VOLKMER. How much of that do you attribute to ongoing costs nonrelated to commercial?

Mr. SALIN. That is a very good question. Based on the information that I was able to tell from the budget, I was certainly not able to differentiate that. Now, if it turns out that there are capabilities which are completely and only used for research, completely and only used for defense purposes——

Mr. VOLKMER. You have got things in there, such things as the manned maneuvering unit in the past. You have got such things in there as studies for the Space Station.

Mr. SALIN. Well, if so, the question then would be in what amounts. I believe the only line items out of that "Total Other Shuttle-related Costs" that would have any sensitivity at all for my numbers, not for my conclusions, but just for the overall numbers, would be the line on production operation capability development or the line on program management.

Now, the program management number, it is my understanding, are NASA's own estimates.

Mr. VOLKMER. All right. I won't argue with that number, but then, let's take the production operation capability and development numbers. Now, you are putting those all again, if I were developing an ELV or whatever and I had so much up front to develop it, I don't try to charge that at all in my first one, or two, or three units, do I?

Mr. SALIN. It varies with the business situation. From an accounting point of view, you don't have to.

Mr. VOLKMER. Don't you amortize?

Mr. SALIN. You amortize it from a cash flow point of view. From an accounting point of view, you would depreciate those expenses over time. From a cash flow point of view, it is normally the practice of a business firm to charge as high prices as it can early on when it often has many cash needs, including the needs of additional investment, so that it doesn't have to externally raise money on the market and externally finance things.

Therefore, the important question here is, if a Delta or a vehicle like it is profitable enough, then in every year it will be able to, from a cash flow point of view, pay for a certain amount of value engineering and investment every year. I believe this would have happened in the Delta program if the Delta had not been essentially terminated.

Mr. VOLKMER. But in this line item of product operation capability development, you have items basically in there, that, in my opinion, should be amortized over a longer period of time than the time which you are amortizing it.

Mr. SALIN. Sure, I agree. That is fine.

Mr. VOLKMER. Another thing that is interesting to me is that in your executive summary, you estimate that the Delta launches costs will fall.

Mr. SALIN. Yes, I believe that is true.

Mr. VOLKMER. And Delta has now made 175 flights.

Mr. SALIN. Yes.

Mr. VOLKMER. How will they fall?

Mr. SALIN. OK, that is a very good question, and I think I mentioned that I recognized that this was a controversial point. The idea of experience curves is a very complex one, but very simply, those are not 173 identical Deltas. Those are 173 evolving vehicles which have had the label Delta, and the actual history of the program is that every year or two, they were making an upgrade, where 1 year they would upgrade the solids on the side, they would upgrade the central core, 1 year they would upgrade the second stage. Now, each time you do an upgrade on a product, you are actually starting, to some extent, a new experience curve. In that sense, the Delta is in every year on a slightly different experience curve and has a lot of potential.

Second point, and equally important, I believe, is that there are two different kinds of ways of pushing experience curves. One of them is that you are pushing your technical capability, and sort of, cost no object. In other words, I don't know to what extent the improvements that have been made in Delta already over the years were primarily directed just to getting the amount of payload up without trying to increase the cost effectiveness, let's say, of production or operations of the Delta.

My suspicion is that in future years with private companies offering the Delta, the improvements will be made not just from the point of view of trying to get the amount of payload up a little bit, but of trying to get the cost of productions and operations down. I suspect that there is a great deal of experience that could be incorporated there.

Mr. VOLKMER. But, again, as I understand just now your testimony, a lot of it is based on conjecture, basically.

Mr. SALIN. Yes, no question. What I have endeavored to do here more than anything else, sir, is to present a set of findings, hypotheses, ways of looking at things, and simply to say, "look, this is the way it looks to me. It seems to me very important. Please consider it for yourself, and to the extent that your judgment is that there is merit in what I am saying, consider the implications."

Mr. VOLKMER. Also, as I understand your reasoning, the shuttle related R&D that will be ongoing in the next 5 or 6 years, that would be included in the NASA charges to users?

Mr. SALIN. That is my basic—I have answered that in two separate places, so I have to say both yes and no. If we are trying to estimate the average cost of the Shuttle program per launch, a certain amount of R&D expense in each year is normally expensed by a company. In that sense, the answer is yes, that should be considered part of ongoing costs of the shuttle way of doing things.

In the sense of a different part of my testimony where I talk about my own personal hunch as to what is supportable in the market, I don't really believe that it is necessary or appropriate to raise shuttle prices all the way to average costs in each year.

First of all, average costs are coming down year by year, and therefore, you wouldn't want to raise them all the way up there right away. Second, there is so far to go, that even if you simply raised towards average costs over the next 10 years, gradually and steadily, by that time the amount of R&D in each year may be comparable to what a private firm would have to pay.

Mr. VOLKMER. So, what we are saying, basically, is that R&D by the Government should be recoverable.

Mr. SALIN. At least where that R&D is specifically to provide capability for commercial business, yes. Where it is completely unrelated to commercial business, no.

Mr. VOLKMER. Well, let's put it this way. If you take any type of applied technology by the Government today, you can look in the field of aeronautics, let's take away space a little bit and let's just go into aeronautics, we are doing a lot today and have been in the past throughout the history, back to 1914 or so, without which we probably would not have the commercial fleets that we have, we wouldn't have Boeing and Lockheed and——

Mr. SALIN. May I clarify something, because I can see there is a real ambiguity here and it is an important one. There are two completely different kinds of research which are getting lumped together by NASA under the term "research." One is "basic" research or "scientific" research. The other is what is normally called in industry, "research and development work" in the sense of the development side, developing a specific product.

Now, my basic argument is that where NASA is developing a transportation system, that part of research is not the same kind of

research. The other kind of research, basic research such as you are alluding to, certainly not, should definitely not be collected from customers. That is part of NASA's basic mandate.

Mr. VOLKMER. Wait a minute now. Right now, just to give you an idea—I think you don't understand everything that NASA does. Let's take in the field of aeronautics. Right now we are developing and have been developing jet engines that are more fuel efficient and with less noise. That is not just basic research.

Mr. SALIN. I understand the point that there is a gray area in between. Let me ask you this——

Mr. VOLKMER. We are looking at products that will be able to do basically the same and transport planes at faster speeds with props basically for one industry.

Mr. SALIN. OK, that is a very important point. Let me ask the following question. Such research is made available to all the different aviation companies, and let me ask you, does a General Electric when it is developing its engines, also have its own research budget? What I am saying is that research on the space shuttle main engine is research of a more applied kind than research on the principles of liquid hydrogen engines or the principles of what are some of the theoretical problems in the design of liquid hydrogen engines.

I am just trying to distinguish those two. Obviously, I can't distinguish which is which inside these numbers.

Mr. VOLKMER. Let me give you one example. You just mentioned it. You helped me more than I could to help you try to understand a little bit about the total NASA budget. The reasons for improving the main engines are twofold. One is a thrust factor running at 109 percent, and for a longer period of time, and basically, that 109 percent is needed for DOD, yet the costs of that are in here.

Mr. SALIN. Yes.

Mr. VOLKMER. It is not commercial. We don't need it for commercial, for those commercial flights.

Mr. SALIN. This kind of an argument definitely reduces, and I would expect to see these numbers reduced at the level of the average cost. I am not sure that they really affect the marginal cost that much.[1]

Mr. VOLKMER. You have also in here—we have to realize do we not, that we are going to have ongoing both DOD and NASA flights, whether we have any commercial or not?

Mr. SALIN. Yes.

Mr. VOLKMER. And you can't tell me right now what the total costs would be for those flights?

Mr. SALIN. No, I can't.

Mr. VOLKMER. And how much the taxpayers would have to pay for those?

Mr. SALIN. No.

Mr. VOLKMER. Let's take a little bit different look at it. Let's see if you want to back and do a little bit more and then you can come back. See if you can determine the total cost of the shuttle operation, eliminating the commercial, not from your viewpoint, what

[1] See "Replies to Questions" regarding whether NASA is in fact planning to use the 109 percent engines to support commercial missions.

would be left if we take the commercial flights out, what would be left for DOD and for NASA flights and how much the total cost for that would be.

Mr. SALIN. Right.

Mr. VOLKMER. Then, that is the difference. That is the cost of what the commercial flights are.

Mr. SALIN. That is a very valid way of estimating the difference. Let me point out carefully.[1]

Mr. VOLKMER. First you have the four shuttles, you have all those costs, you have all the astronauts, you have all the people at Johnson, at Kennedy, you still have people at——

Mr. SALIN. Wait a minute. I thought earlier we had a discussion on the question of whether they would all be there 5 years from now.

Mr. VOLKMER. I think what you need to do though, and you have admitted to me, and I think what you need to determine is before you can make these, in other words, even economic determinations, is how many of those people will be there, and you do not know.

Mr. SALIN. I do not know. That is correct.

Mr. VOLKMER. We cannot just assume for a basis to say that the Shuttle flights are so much, we cannot just assume that they will be different than they actually are.

Mr. SALIN. No. Oh, excuse me. What I am claiming, sir, is that the assumptions that are the basis of NASA's estimates at least seem to me questionable, and I have attempted to show that they are subject to question. I am absolutely not asking you to adopt my assumptions. I am asking you to consider completely reviewing the matter from the point of view of a businesslike standpoint and from the point of view of competition with other businesses which must, of necessity, price based on their cost structures.

If I may add one point——

Mr. VOLKMER. Apparently, you did not consider approximately 10 percent of the 1986 costs, 20 percent of the 1987 costs, and 50 percent of the 1988 costs are for flights that occur subsequent to 1988.

Mr. SALIN. That is correct.

Mr. VOLKMER. That also would be a flaw in your analysis, would it not?

Mr. SALIN. It would change the numbers. It would certainly make it more complex, but I have attempted to make the overall analysis as simple as I possibly could. The reason for that is two-fold. First, my ability to obtain too much more detailed numbers is quite limited. Second, there are levels of complication of analysis which are second order and third order effects. I can try to get out on the table what I think are first order effects, but I don't think they change the conclusions.

Mr. VOLKMER. You don't think it changes the conclusions?

Mr. SALIN. That is right. The conclusions I am talking about, the substantive implications for American space policy and for shuttle pricing policy. In other words, you would definitely come out with different numbers. The reason I have come up with these numbers is not because I am trying to claim that you or anyone should

[1] The witness believes that his response "states a position I do not support."

adopt one of these numbers as the right number, but because of their overall implications.

Mr. VOLKMER. All right. I have one other thing. I just hope I may be able to help you understand a little bit about what NASA does and what is going on. If, in commercial ELV's and we hope it all works and we have the Atlas and the Delta and we hope it goes, if they go down to Canaveral to launch those, how much should we charge them?

Mr. SALIN. Full cost.

Mr. VOLKMER. Full cost?

Mr. SALIN. Yes, sir.

Mr. VOLKMER. You know what that does to them? You would put them out of business. So, what is all this about? If the shuttle doesn't fly, they are not going to fly against Ariane at full cost down there.

Mr. SALIN. The numbers that I had seen on the charges that have been made by the Government in the past on those launches——

Mr. VOLKMER. Are not full cost.

Mr. SALIN. OK.

Mr. VOLKMER. They are additive costs.

Mr. SALIN. Are they?[1]

Mr. VOLKMER. Yes.

Mr. SALIN. That is an extremely important point.

Mr. VOLKMER. Yes. You see, that is the whole thing. Do we want an industry in this country or don't we? I think before we criticize it too much, we better fully realize what is being done in the total realm of things.

When you look at Ariane, that is being subsidized also.

Mr. SALIN. Yes.

Mr. VOLKMER. Now, we have to look at it, I as a representative, my taxpayers, I will go back to them again, it is just a question of do we continue an operation that we have some expertise in or do we let somebody else do it? If we don't do what we have been doing, somebody else will.

Mr. SALIN. Yes. May I ask one question regarding the full cost of launches. While, if the full cost numbers for launch operations for, let's say a Delta or Atlas Centaur, are 5 or 10 times the numbers that are being charged, and I don't know, I am just——[2]

Mr. VOLKMER. It depends on what you want to put in there. If we want to put in the total cost of putting those in, the total R&D, and we want to put in the total— amortize out all total labor costs that we have to have down there anyway whether we put one commercial up or not, if we want to take all of that and those expenses connected with it, and the transportation out there and putting them on the pad—if you want to do that——

Mr. SALIN. When I said full cost, I meant the ongoing cost: The costs of supporting that activity. Now, it is difficult to estimate, and we are talking about cost estimation. That is what I think. Now, if those costs are so much higher than what has been charged, I would certainly want to point out the possibility that the

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[1] See "Replies to Questions.

[2] See: "Replies to Questions."

people operating the Delta or the Atlas Centaur might decide that they could do it themselve more cheaply.

Mr. VOLKMER. That is something maybe you had better examine before you make that statement as to what it would cost them to do it by themselves.

Mr. SALIN. In that case, you see, I would have to be a party to their cost estimates, and as with NASA——

Mr. VOLKMER. They would have to build a complete pad and would have to arrange safety. They are going to have to have being able to have tracking facilities, all these things.

Mr. SALIN. Yes.

Mr. VOLKMER. That is pretty much of an expense.

Mr. SALIN. Yes.[1]

Mr. VOLKMER. Maybe you ought to determine how much that would cost them before you say they might want to do it themselves.

Mr. SALIN. Yes.[2]

Mr. VOLKMER. Well, thank you very much. I appreciate your testimony. I do think that I would appreciate it if you would examine and get back to me what the total basic costs would be if the shuttle—if we still ran the DOD and the NASA flights and no commercial flights, as to what that cost would be.

Mr. SALIN. Respectfully, sir, I don't think there is any way I could estimate that. It would require NASA and independent accountants working for months, I would believe, to make their own independent estimate of that number. As a private citizen, I don't——

Mr. VOLKMER. Well, you see, I see it a little bit differently. I see that as the cost to the taxpayer and then, what is additional, that is the cost of the commercial.

Mr. SALIN. I understand. I am saying that my ability to estimate such a number——

Mr. VOLKMER. I have a completely different way of doing it than you are doing it.

Mr. SALIN. Yes. Now I am saying that my ability to estimate that number as a private citizen is distinctly limited.

Mr. VOLKMER. OK.

The subcommittee will stand adjourned until 1 p.m. tomorrow.

[Whereupon, at 3:25 p.m., the subcommittee recessed, to reconvene at the call of the Chair.]

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[1] See: "Replies to Questions."
[2] See: "Replies to Questions."

1985 NASA AUTHORIZATION

WEDNESDAY, FEBRUARY 29, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee met, pursuant to call, at 1:07 p.m., in room 2325, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Present: Mr. Nelson, Mr. Lujan, Mr. Walker, and Mr. Watkins.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

Today the subcommittee continues its deliberations on the NASA fiscal year 1985 budget request. Our focus today is on NASA's Office of Tracking and Data Systems and the Office of Technology Utilization.

These programs are not the most highly visible programs in NASA. Nevertheless, they serve a vital function and have contributed significantly to the success of NASA.

This past year saw the first launching of the tracking and data relay satellite (TDRSS). Despite deployment problems and failures in some of the thrusters and electronic components in the satellite, it has performed splendidly, particularly in support of the first spacelab mission. The problems with TDRSS, however, are troubling. Schedule delays and cost increases in the program simply must be brought under better control. We will address these matters with our first witness, Mr. Robert Aller, Associate Administrator for the Office of Tracking and Data Systems, who will be presenting the budget request for this office.

Mr. Aller will be followed by Mr. Patrick Templeton, Associate Administrator for External Affairs, and Mr. Ronald Philips, also from the Office of External Affairs. Mr. Templeton and Mr. Philips will discuss NASA's technology utilization program.

The committee takes great pride in the technology utilization program, and we are especially pleased to see an increase in the funding request for this effort. This program has the potential to benefit many individuals and businesses and to display the genius of NASA and its people in a tangible way.

Gentlemen, I want to welcome you here before the subcommittee. The gentleman from New Mexico is recognized for an opening statement.

Mr. LUJAN. Thank you, Mr. Chairman. I do not have a formal opening statement. I just want to say, one of the things that occurred to me, perhaps an offshoot of what we are trying to accom-

plish in TDRSS was that it did not work, and the amazing thing that thousands of miles away we were able to direct it, and that in itself is quite an accomplishment, probably just as important as the information that we will get back from TDRSS. Of course, the technology utilization, that is what the whole program, any Government program is, to be able to use it for the benefit of mankind. I look forward to listening to the testimony.

Mr. Chairman, there are always so many meetings, and my other subcommittee is meeting on the other side on magnetic fusion, but I will stay and listen to the witnesses. Thank you very much.

Mr. VOLKMER. Thank you.

At this time, Mr. Aller, you may proceed. Your statement will be made a part of the record, and you may review that or summarize, however you desire. You may proceed.

STATEMENT OF ROBERT O. ALLER, ASSOCIATE ADMINISTRATOR FOR SPACE TRACKING AND DATA SYSTEMS, NASA, ACCOMPANIED BY NORMAN POZINSKY, DEPUTY, AND RONALD DAPICE, DIRECTOR OF ADMINISTRATION AND RESOURCE MANAGEMENT

Mr. ALLER. Thank you, Mr. Chairman, members of the subcommittee. It is a pleasure to make my first appearance before this subcommittee to present the fiscal year 1985 budget request for the space tracking and data systems program. Seated at the table with me are Mr. Norman Pozinsky, my deputy, and Mr. Ronald R. Dapice, the Director of Administration and Resources Management. I will summarize my submitted statement and will emphasize the major elements of the budget.

Our program is in the midst of change relative to the configurations of NASA's space tracking and data networks. As you are aware, we have already begun the transition from the traditional ground network support of low Earth orbiting spacecraft to a space network support of low Earth tracking and data relay satellite (TDRSS). The deep space network is also undergoing change and is being reconfigured to enhance its capabilities to support distant planetary missions. We are also combining station resources at the three deep space network stations to provide support to Earth orbiting satellites not compatible with the TDRSS.

In the interest of time, I will not go into the details of each program since they are included in my statement for the record. However, I would like to briefly review the major aspects of our fiscal year 1985 budget requirements. We are requesting, as shown in figure 1, a total of $811.0 million for the four major elements of our budget, which are: Space network—basically the TDRSS, ground network, communications and data systems, and advanced systems. It is important to note that approximately 75 percent of our budget request represents funds to continue to provide vital operational support to ongoing NASA flight programs, with the balance for systems implementation and a small amount for research and development. In fiscal year 1985, support will continue for ongoing missions along with preparations for upcoming missions. I would like to point out at this time that our budget submission is based on the

current STS manifest which shows the launch of the second TDRS spacecraft in late 1984, and the third TDRS in early 1985. Based on recent developments late last week, these launches are not expected to occur until early 1985 for the second TDRS and mid-1985 for the third TDRS. This will cause a further delay in the planned closure of our ground station. We are in the process of assessing the budget impact at this time.

[Figures 1-9 appear at the end of Mr. Aller's prepared statement, see p. 913.]

I would now like to discuss our space network program, the first element in our fiscal year 1985 budget. I will briefly review our progress since the last hearings. A significant step toward an operational space network was taken with the launch of the first TDRS in April 1983. The spacecraft was the first payload of the space shuttle Challenger, and the first NASA use of the inertial upper stage [IUS]. Although the spacecraft was not initially placed into its nominal orbit, the spacecraft's small thrusters—I have one on display here; this is an actual thruster off one of our spacecraft—using its small thrusters to place it into orbit.

The next chart (figure 2) detects the TDRS mission recovery. On June 29, 1983, geosynchronous altitude was achieved. What happened on that particular launch was the IUS put us into an orbit of a 22,000-mile apogee and a low point of approximately 13,000 miles. The operation, which took place over the 3-month period and consisted of 39 maneuvers, were maneuvers around the apogee point. Every time we came around apogee we would burn two of these small thrusters for periods of about 10 minutes to an hour and eventually raised the orbit on June 29 to geosynchronous.

I would like to off the record state that in my 25 years in the space business the engineering that went into that activity is the most outstanding I have ever seen or been a part of.

Once deployed in geosynchronous orbit, the TDRS has supported the STS-8 mission and the Landsat program as part of the on-orbit TDRSS program. Figure 3 is a TDRSS relayed Landsat photo of the San Francisco area. The picture itself is not significant. However, the significance of it is the first day the TDRSS supported Landsat in July last summer we were able to transmit thematic mapper data at a zero error rate. The significance of that is that normally in transmitting any data you have significant errors in the data, what we call dropping a bit here or there, a hit on the signal, and TDRSS was able to process this Landsat data error free. The performance of the network was more severely tested when the first TDRS successfully accomplished the primary support role for the first Spacelab, STS-9, mission which was launched in November of last year. The TDRS and the other space network elements performed exceptionally on that mission in providing near-perfect operational support. In addition, during February 1984, TDRS successfully supported the STS-41B mission.

The first TDRS spacecraft, however, in the fall of 1983, experienced failures in one of the communications links used to send voice and data to the user spacecraft. Figure 4 depicts the communications link that has given us the problem. We plan to correct this problem prior to the next TDRS launch. On this chart, it is a line diagram that shows what has happened on the TDRSS. We

have two links in these large antennas that allow us to transmit from the ground through the satellite out the antenna to the user spacecraft, in this case the shuttle. In the compartment behind the antenna are the elements that are causing the problem, the diplexer, a device that allows us to separate the transmitted signal from the received signal, and an amplifying device, so-called TWTA amplifier. We have on each side of this two amplifiers and one diplexer, one for each antenna. On one side we had a failure of the TWTA device and we have had a failure of the diplexer. The TWTA itself is redundant, there are two of those. However, they both play through the diplexer, so with the diplexer failure we cannot process the forward K band to the user spacecraft.

On the other side, the other antenna, we have had a failure of a TWTA. The diplexer is all right. So on one side of the spacecraft we have an operable TWTA and a diplexer. We presently have that turned off because we do not have a support program that requires that forward link. We are operating successfully on S band forward and we have performed that way with both Landsat and shuttle. This is the power amplifier where we are having the problem. This is the tube itself, the power supply in back. These are built by Hughes and it is the power supply where we think we are having the arcing. This is the diplexer. There are five tuning screws and we believe in that area is where we are having the problem with the diplexer.

Mr. LUJAN. With the tuning screws? It is not properly tuned?

Mr. ALLER. We think the procedure for tuning was incorrect and as a result of the process we have contamination in the diplexer; a contamination that consists principally of some copper chips as a result of perhaps running the screws too far down into the housing around the screw. The tuning screws are approximately the size of the screw on your glasses and there were five of these and we have found problems in diplexers we have on the ground, and that is why we believe that is the problem we have experienced on board.

Production of the remaining TDRSS program spacecraft is continuing. The second TDRS was completed last July and placed in storage. It has since been removed from storage and is currently undergoing maintenance testing and will be reconfigured prior to launch. The third TDRS has completed environmental testing and is in the final stages of integration testing and assembly. The fourth, fifth, and sixth spacecraft are in various stages of assembly.

The fiscal year 1985 space network budget requirement of $386.5 million is needed to provide for bringing the TDRSS to full operational capacity with the second and third launches, providing a full Federal finance bank payment, funding for follow-on spacecraft, initiating the funding of operation and maintenance payments for the White Sands activities, and for providing full TDRSS operations at the Goddard Space Flight Center. Successful establishment of the three operational spacecraft on orbit will achieve operational status of the space network and permit the phasing out of designated ground stations.

The ground network is the second budget element, for which we are requesting $223.6 million for fiscal year 1985. The ground network consists of the spaceflight tracking and data network [STDN], managed by the Goddard Space Flight Center, the deep space net-

work, managed by the Jet Propulsion Laboratory, and ground tracking and data acquisition support for aeronautics, balloons, and sounding rockets programs, managed by the Dryden Flight Research Facility and Wallops Flight Facility.

The spaceflight tracking and data network [STDN] supports launch and low-Earth orbital missions, which includes extensive support to the Space Shuttle. We had previously planned to close or transfer to other users the majority of the STDN stations beginning about April 1984. However, due to delays associated with the IUS, we plan to extend the STDN ground station operation, as shown in figures, to mid-1985, when the TDRSS is expected to achieve full operational capability. Our budget submission is based on an April 1985 station closure date, but recent IUS developments now lead us to conclude that this date is no longer realistic and we are developing plans to extend station operations to later in the year. Those stations remaining will be consolidated with the deep space network or dedicated to launch and landing support.

This particular chart I believe has been shown to you before. There are no changes on it except for the cross-hatched area for the last year with the IUS problem extending the station closures from this year until next year and the latest IUS development will extend it a few months longer.

The deep space network supports planetary and interplanetary flight projects. Along with the networks consolidation, major upgrades are underway in the deep space network to increase the capability to support spacecraft on their way to distant planets. Upgrades underway will enhance the ability of the deep space network to receive weaker signals, provide support to an increasing variety of spacecraft, and provide more precise navigation. Figure 6 is a picture of the high-efficiency 34-meter antenna under construction at the Goldstone Station in California. An identical antenna is also under construction at the Canberra Station in Australia. You can see the smaller antenna under construction with the quadrapod on the ground that holds the feed horns. The antenna in the background is the big 64-meter dish that we plan later to extend to a 70-meter dish. A critical milestone for this activity as I will explain to you in figure 7 is to increase the capability for the deep space network to support the Voyager encounter with Uranus in early 1986. This chart illustrates the changes underway at our three deep space stations. First, each antenna system at a site is tied to a single control and data retrieval location called the signal processing center. You can see at each site it is labeled SPC. Previously, each antenna had its own control facility. Network consolidation is accomplished by integrating the 26-meter antenna at each location, previously operated by GSFC/STDN management. These systems can be used singly or by arraying the antenna to increase the effective aperture at the sites. For instance, for the Uranus encounter, we plan to array the three Canberra antennas with an additional 64-meter antenna at Parkes, Australia, that is owned and operated by the Australian Government, to obtain an effective aperture of 2.45 at that site. We are arraying two 34 meter, the 64 meter that we have at our site, and the 64 meter at Parkes. We are able to do this because of the work done out of our R&D effort in

the orange and the development of very accurate timing and very low-noise receivers that we have in these antennas at this time.

Mr. LUJAN. While you have the map there, what will these three receivers—you are upgrading Goldstone and Canberra, I guess maybe Madrid also——

Mr. ALLER. Yes, sir.

Mr. LUJAN. It was my understanding that TDRSS would be receiving all of the communications.

Mr. ALLER. Let me clarify. I am now speaking of what we call the deep space network.

Mr. LUJAN. TDRSS is for those that can be reached——

Mr. ALLER. Lower; yes, sir. This is our support of planetary programs. These three sites are basically operated under the control and managed by JPL on the west coast. The rest of the system is managed by Goddard.

The third major budget element is the communications and data systems program for which we are requesting a total of $185.6 million. It includes communications, mission control, and data processing. This chart (figure 8) shows the manifesting or the schedule on the ground network from 1984 to 1989, and I will not dwell on that any more than to point out the upgrades that we have in the 1985 budget for Madrid and the upgrades that will follow for Goldstone and Australia allow us to support these Galileo, ISPM missions the Voyager encounter at Uranus, the Voyager encounter at Neptune in 1989.

Next chart, please. This chart (figure 9) shows the vital link between the data acquisition stations and the users. In 1985, for example, emphasis will continue on the development of a control center for the space telescope. Major software developments under way for several years should be essentially completed in fiscal year 1985. This software manages the major operational activities of the space telescope, including spacecraft and subsystem health and safety, pointing the observatory at selected sources, pointing the user antenna at the TDRS, conducting mirror surface calibrations, and focusing the mirror itself. This is called communications and data processing [1] in our budget, and I just would like to take a minute to point out the communications so-called NASCOM here are basically leased circuits from industry that consist of Comsat satellites and landlines. We do the operations and control from Goddard as indicated here. We have a significant computing activity at Goddard that does the trajectory, the attitude, and the command generation, and we do data capture and processing at Goddard. All of these elements are in this portion of the budget.

The three major budget items just discussed are included under space flight control and data communications in the NASA budget. Included under research and development is our advanced systems program for which we are requesting $15.3 million. This small but critically essential portion of our program provides studies and technological developments needed to meet the ever increasing requirements of space programs.

In summary, I would like to again emphasize that we are in a state of transition as we change from NASA's traditional tech-

[1] This program should be called "Communications and Data Systems."

niques of providing network support. Initiation of operational support for flight programs through an operational space network, TDRSS, closure of many of our ground sites, and enhancement and consolidation of the deep space network will make fiscal year 1985 a most challenging year.

The requested funding level space tracking and data systems program budget provides the minimum resources necessary to meet all of our support requirements in this time of transition and to bring the TDRSS to its full operational capability. I reemphasize that this budget request does not include the additional IUS slip.

I appreciate the opportunity to meet with you to discuss NASA's space tracking and data systems program. I thank you for the subcommittee's past support to this aspect of NASA's program, and urge the full support of the subcommittee for the fiscal year 1985 budget request.

I'll be happy to answer questions at this time.

[The prepared statement of Mr. Aller follows:]

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PRESENTED BY WITNESS

STATEMENT OF

ROBERT O. ALLER

ASSOCIATE ADMINISTRATOR FOR

SPACE TRACKING AND DATA SYSTEMS

National Aeronautics and Space Administration

before the

Subcommittee on Space Science and Applications

Committee on Science and Technology

House of Representatives

Mr. Chairman and members of the subcommittee:

It is a pleasure to make my initial appearance before this subcommittee, as the Associate Administrator for Space Tracking and Data Systems. I will describe the FY 1985 budget request for the NASA Space Tracking and Data Systems Program.

The Space Tracking and Data Systems Program is in the midst of change with respect to the configurations of NASA's tracking and data networks. As you are aware, there has already begun the transition from the traditional ground network mode support to low Earth orbiting spacecraft to the Space Network mode with the Tracking and Data Relay Satellite. FY 1985 will be a particularly challenging year with the launching of two additional Tracking and Data Relay Satellites (TDRS) and the completion of required testing to bring the TDRSS to full operational capability. Achieving these milestones will complete the transition to this new era of operational support of low Earth orbital missions.

With the TDRSS operational, many of the existing ground stations will no longer be required and will be closed or transferred to other agencies. The designated stations remaining will be consolidated with the Deep Space Network (DSN) under the operation and management of the Jet Propulsion Laboratory (JPL) or dedicated to launch and landing support. This consolidation will result in a single ground network to support all deep space probes and planetary missions, geosynchronous and highly elliptical orbit spacecraft, as well as older spacecraft which are not compatible with the TDRSS.

Along with this consolidation, major upgrades are underway in the Deep Space Network to increase the capability for DSN support to spacecraft to distant planets. Upgrades underway will enhance the ability to the DSN to receive weaker signals, provide support to an increasing variety of spacecraft, and provide more precise navigation. A critical milestone for this activity is to increase the capability of the DSN to support Voyager 2's encounter with Uranus in early 1986. The Space Tracking and Data Systems Program continues to provide a global communications system which links tracking stations to control centers. Data systems facilities provide real time data processing for mission control and orbit and attitude determination, as well as routine processing of telemetry data from space experimenters.

In addition to discussing my budget requirements, I will also review significant accomplishments and activities since last spring and discuss our current support services to all NASA flight programs. At this time, I would like to quickly highlight activities during calendar year 1983.

HIGHLIGHTS

The ground networks provided excellent support to NASA's flight programs, both for near-Earth orbiting satellites such as the Space Shuttle missions and for deep space probes. Some of those STDN missions supported were the Space Shuttle missions 6, 7, 8, 9 and 41B, and the TDRS-1 launch and deployment.

The Deep Space Network (DSN) supported approximately ten spacecraft as they continued exploring interplanetary space. One of these missions, the Pioneer 10, is now beyond the outermost planets and is by far the most distant man-made object in the universe. Radio waves from the DSN must travel almost 4 1/2 hours to reach it. Another DSN achievement was making unique measurements of a comet by using a large antenna as a radar. The DSN also began supporting our newest interplanetary probe. The ISEE-3 spacecraft used the moon's gravity to change trajectory for an encounter with a comet, and has been renamed the International Cometary Explorer (ICE).

However, most of the DSN's attention is focused on the future. The network upgrade referred to above is well underway, as is the networks consolidation program. I will discuss these in more depth later.

The first TDRS was launched on the STS-6 mission in April 1983, and was deployed into an elliptical, rather than synchronous, orbit as a result of an anomaly during the second stage burn of the Inertial Upper Stage (IUS). Through a series of orbital adjust maneuvers, utilizing the spacecraft's small thrusters, the TDRS-1 was successfully boosted to a geosynchronous orbit, enabling it to provide data relay services. After an intensive test program, concentrating on the activation of user services, TDRS-1 successfully supported the STS-8, STS-9/Spacelab-1, STS-41B and Landsat-4 missions.

During the STS-9/Spacelab-1 mission, all requirements were met by our communications circuits. This included the 50 megabits per second wideband data handling circuit from the White Sands TDRSS ground terminal to the Goddard Space Flight Center (GSFC) and the Johnson Space Center (JSC).

Our Spacelab Data Processing Facility (SLDPF) also successfully supported the first Spacelab mission. During the ten day flight, almost five trillion bits of data were acquired from the Spacelab experimenters. These data are being processed and delivered to the U. S. and European Space Agency (ESA) investigators on schedule.

Development is continuing on the Space Telescope control center to support a 1986 Space Telescope launch. Control Center hardware at the Goddard Space Flight Center (GSFC) was installed during 1983 and a capability demonstration to support the low data rate channels of the Space Telescope was successfully conducted.

Having touched on some of the highlights of our program during calendar year 1983, I will now turn to our pending budget request and the challenges ahead for FY 1985.

FY 1985 BUDGET REQUEST

For FY 1985, we are requesting a total of $811.0 million to continue to provide tracking, command, data acquisition and data processing support to NASA flight projects. In FY 1985, support will continue for ongoing missions along with preparations for upcoming missions.

The increase from the current FY 1984 budget to the FY 1985 request is due primarily to the requirements in the Space Network. These requirements include payments to the Federal Financing Bank (FFB) for the TDRSS loans, provision for the impact of the anomaly that occurred during deployment of the first Tracking and Data Relay Satellite, funding for continuing TDRS spacecraft production, the initiation of cost plus award fee arrangement for maintenance and operation for the White Sands Ground Terminal, TDRSS integration with the Centaur Upper Stage and for service payments to the TDRSS contractor. Other factors such as inflation and additional data processing requirements also contribute to the increase from FY 1984 to FY 1985. The subsequent portion of my statement addresses, in detail, the various program areas.

SPACE NETWORK

In FY 1985, we are requesting $386.5 million for the Space Network program. The Space Network consists of the Tracking and Data Relay Satellite System and the associated NASA ground systems necessary to provide support services to low-Earth orbital satellites compatible with the TDRSS. The elements of this network are the Tracking and Data Relay Satellites and the White Sands Ground Terminal (WSGT) of the TDRSS, the Network Control Center (NCC), the Operational Support Computing Facility (OSCF), the Simulations Operations Center, the Compatibility Test Vans,

the Bilateration Ranging Transponder System (BRTS), and the NASA Ground Terminal (NGT), colocated with the WSGT in New Mexico.

The TDRS spacecraft and the WSGT provide the communications between the ground and user satellite in both command (forward) and telemetry (return) modes. Other elements of the network interconnect the ground control facilities of the user satellite with the TDRSS. Specifically, the NGT monitors TDRSS performance and performs trouble shooting and system verification functions for the network. The NCC schedules TDRSS services for all users and serves as the focal point for user interaction with TDRSS. The OSCF provides orbit determination and time correlated position location for all Earth orbiters supported by the Space Network and the Spaceflight Tracking and Data Network (STDN). The BRTS provides precision position location for the TDRS. The Simulations Operations Center and Compatibility Test Vans provide necessary testing, simulations, and interface verification for the user spacecraft and space network elements to assure operational readiness prior to the launch of a given mission. Together, these elements constitute the Space Network.

A significant step toward an operational Space Network was taken with the launch of the first TDRS in April 1983. The spacecraft was the first payload of the Space Shuttle Challenger, and the first NASA use of the Inertial Upper Stage (IUS). A major setback occurred in the launch sequence with a failure of the second stage of the IUS. Rather than placing the TDRS in a circular orbit at geosynchronous altitude of 22,234 miles, the spacecraft was placed in an elliptical orbit from which data relay services are not provided. A complicated series of 39 spacecraft maneuvers, using its tiny one pound thrusters, was necessary to reach geosynchronous orbit on June 29, 1983. Subsequent investigation has determined the probable cause for the IUS failure, and corrective measures are underway. However, it will be some time before the next IUS will be ready for launch, and the TDRSS Program has been delayed as a result.

Once deployed in geosynchronous orbit, the TDRS-1 has supported the STS-8 mission and the Landsat Program as part of the on-orbit TDRSS test program. The performance of the network was more severely tested when the first TDRS successfully accomplished the primary support role for the first Spacelab, STS-9, mission which was launched in November 1983. The TDRS-1 and the other Space Network elements have performed exceptionally on that mission in providing near perfect operational support. In addition, during February 1984, TDRS-1 successfully supported the STS-41B mission.

Production of the remaining five TDRSS spacecraft continues. TDRS-B was completed last July, placed in storage, and is currently undergoing maintenance testing and reconfiguration; TDRS-C has completed environmental testing and is in the final stages of integration testing and assembly; TDRS-D, the first ground spare, is in the assembly and integration process and will begin environmental testing later this spring. TDRS-E and F are in the initial integration phase with completion anticipated in 1985.

The TDRS-1 spacecraft has experienced failures. Thruster failures required deactivation of 13 of the 24 thrusters on-board, further complicating the orbit correction maneuver sequence. The high data rate command link, the Ku-Band forward, also experienced component failures. This reduced two fully redundant K-Band forward channels to a single channel without redundancy. These failures are under investigation and we plan to correct them prior to the next TDRS launch.

The current schedule anticipates the launch of our second spacecraft in late 1984 and the third launch in 1985. When three TDRS spacecraft are on-orbit and functioning, the closure of the designated Ground Network stations will begin.

GROUND NETWORK

To meet the Ground Network support requirements for FY 1985, we are requesting a total of $223.6 million. The Ground Network consists of the Spaceflight Tracking and Data Network (STDN), and the Deep Space Network (DSN), and ground tracking and data acquisition support for the Aeronautics, Balloons and Sounding Rocket programs.

In FY 1985, we will look forward to continuing the support of NASA flight projects, both for near-Earth orbiting satellites, including the Space Shuttle operational flights, and for deep space probes. Numerous applications and scientific Earth orbiting missions will be supported including the Active Magnetospheric Tracer Explorer (AMPTE), Nimbus-7, NOAA Landsat, International Ultraviolet Explorer, International Sun Earth Explorers, Solar Maximum Mission, and the Solar Mesospheric Explorer. Planetary mission support will continue for Pioneers 10 and 11, Pioneer Venus, and Voyagers 1 and 2, as well as limited support for Helios and earlier Pioneer missions. In addition, the DSN has assumed tracking and data support responsibility for the International Cometary Explorer (ICE).

SPACEFLIGHT TRACKING AND DATA NETWORK (STDN)

The Spaceflight Tracking and Data Network (STDN) supports launch and low-Earth orbital missions, which includes extensive support to the Space Shuttle. The projected STDN workload in FY 1985 includes support of about 30 launches, scientific and application missions. To accomplish this support, we have operated and maintained 11 S-Band stations, augmented by two Space Shuttle special purpose stations (Dakar, Senegal, and Ponce de Leon, Florida) and two UHF air-to-ground voice sites for STS communications purposes. Since our last testimony, we closed the Shuttle special purpose station at Buckhorn, California, which was used to support Shuttle landings at Edwards Air Force Base. We were able to augment the facilities at the Dryden Flight Research Facility to provide a reduced but acceptable capability to cover landings of the Space Shuttle.

We had previously planned to close or transfer to other users the

majority of the STDN stations beginning about April 1984. However, due to the IUS anomaly experienced on the launch of the TDRS-1 satellite, we plan to extend the STDN ground station operation until at least April of 1985, when the TDRSS is expected to achieve full operational capability. We will then cease operations at Ascension Island; Santiago, Chile; Guam; Hawaii; Dakar, Senegal; and Gaborone, Botswana. At the same time, we will terminate the UHF air-to-ground capability at Yarragadee, Australia, and at the USAF Indian Ocean Station. In October 1984, NOAA will assume management and operational responsibility for our Alaska station. We reduced our capability to a one antenna system at Goldstone, Madrid, and Australia in January 1984. The second antenna at each of these locations will be transferred to the Deep Space Network (DSN) by February 1985, as part of the Network Consolidation Program. Although our budget request for FY 1985 shows some reduction in levels for that year, full savings from closures will not be achieved until FY 1986 due to costs associated with personnel terminations and station closure activities. We are currently negotiating with other government agencies who can utilize our equipment to transfer and dispose of assets at stations to be closed. After the closure and/or transfer actions are completed, the STDN will have three stations remaining. The Bermuda and Merritt Island/Ponce de Leon stations will be retained to provide launch, landing, and pad support. The S-Band station at Greenbelt, Maryland, will be retained to provide limited orbital support to the International Ultraviolet Explorer (IUE), Nimbus-7, Cosmic Background Explorer (COBE), and Interplanetary Monitoring Platform (IMP-8) missions.

DEEP SPACE NETWORK (DSN)

The Deep Space Network (DSN) supports planetary and interplanetary flight projects. The major objective is to provide responsive, but cost-effective, communications with and tracking of scientific spacecraft beyond the immediate vicinity of the Earth. DSN facilities are also used in related scientific research, taking full advantage of unique capabilities. Examples include using the large antennas and sensitive receivers to study other planets and comets through the use of radar techniques, monitoring of signals received during routine tracking for evidence of gravity waves, and mapping of locations of extragalactic radio sources for use as landmarks for precision interplanetary navigation. As we previously mentioned, we plan to consolidate activities of the residual Spaceflight Tracking and Data Network (STDN) with the DSN after TDRSS becomes operational.

This consolidated network will also be able to provide emergency support for spacecraft such as the STS, the TDRSS, and the Space Telescope, as well as permit extending the period of support of several older spacecraft. This network consolidation program is proceeding very smoothly, and will be completed in FY 1985 as planned.

The DSN upgrade, which I previously mentioned, is also proceeding very well. As you may recall, this upgrade will give us a modern, efficient ground network with new capabilities to combine signals

from several antennas to obtain more scientific data. The most pressing need for this capability is to receive more images from Voyager 2 as it encounters the most distant planets of our solar system.

Construction is now over 75 percent complete for the two new 34-meter antennas to increase the capability of the DSN to support Voyager 2's encounter with Uranus in early 1986. Completion is on schedule for September 1984. One antenna is located at each of the DSN stations in California and Australia. The antenna construction is funded under the NASA CoF Program.

During the Uranus Encounter, which will occur some 2.9 billion kilometers from Earth, Voyager 2 will transmit the first detailed images ever made of Uranus. To enhance the data return, the DSN must successfully array multiple antennas. In Australia, this will include the use of the 64-meter antenna of the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO).

Following the Uranus Encounter, the Voyager spacecraft will be targeted to arrive at the Planet Neptune in 1989. Preparations for support of the Neptune Encounter will include, in the FY 1985 construction program, an expansion of the 64-meter antenna to 70-meters and a new 34-meter antenna at Madrid, Spain. These two upgrades are also required for Galileo navigation, for tracking of the Pioneer 10 spacecraft after 1992, and to accommodate the anticipated workload at the Spanish complex.

Extensive preparations are underway to support an especially critical period for the DSN beginning in February 1985. In addition to the Voyager Encounter, the DSN will assume responsibility for some Earth orbital spacecraft from the STDN, support the last AMPTE canister releases and Japan's first interplanetary probe, track the two French-Soviet balloons ejected into the atmosphere of Venus, and support the International Cometary Explorer (ICE) encounter with the Comet Giacobini-Zinner. Ongoing support will continue for Pioneer 10. The DSN will also support the launch and early cruise phases of both the Galileo and International Solar Polar missions. In addition, support will be provided for ESA's Giotto spacecraft encounter with Halley's Comet, including the improved Giotto navigation which will be obtained by tracking the USSR's VEGA spacecraft.

AERONAUTICS RESEARCH, SCIENTIFIC BALLOONS, AND SOUNDING ROCKETS

Another important activity of our Program is the tracking and data acquisition support to the Aeronautics Research, Scientific Balloon, and Sounding Rocket activities, managed by the Ames Research Center (ARC) and the Goddard Space Flight Center (GSFC). Over the years, our facilities have developed into a comprehensive suborbital flight support capability encompassing the complete spectrum of fixed and mobile ground support functions including telemetry, communications, optics, command, space positioning and data processing. For sounding rocket missions, we also perform vehicle and payload impact prediction and range surveillance

functions in support of range safety. We have continued the planned upgrade of facilities at the Dryden Flight Research Facility (DFRF) and the Wallops Flight Facility (WFF).

Accomplishments in 1983 included support by WFF of an expedition to Peru where over 30 rockets were launched in a 30 day period. The 10-foot telemetry antenna at the Poker Flat Research Range in Alaska was replaced with a 16-foot system to improve tracking support. Selection of a contractor for the Real Time Impact Prediction Computer System at WFF is anticipated early this spring. At the DFRF, we continued to experience a high level of research mission activities. The Advanced Fighter Technology Integration Program (AFTI/F-16) successfully completed the flight evaluation of the advanced digital flight control system. A new radar data processing system was implemented and the second Telemetry Acquisition Processing System was brought on line.

Our FY 1985 budget request includes funds to expand our level of operational support and to continue the upgrade of the support facilities associated with aeronautics, balloons, and sounding rocket tracking and data acquisition activities. In FY 1985, we will incorporate into our program the existing tracking and data acquisition functions associated with the Ames Research Center support of rotorcraft research. Major expenditures in FY 1985 will include the first phase of a major upgrade of the radar systems at WFF. At DFRF, we plan to add a second directional antenna system for long range UHF voice communications to accommodate the projected increase in research aircraft flight activity. The Radar Information and Display central processor will be replaced and efforts will continue to upgrade or replace optical, communications, telemetry and control center equipment.

COMMUNICATIONS AND DATA SYSTEMS

For FY 1985, a total of $185.6 million is requested for the Communications and Data Systems Program. The basic elements of this program form the vital link between the data acquisition stations and the users and include communications, mission control, and data processing.

COMMUNICATIONS

The Space Tracking and Data Systems Communications Program consists of NASCOM and the Program Support Communications (PSC). Collectively they comprise almost 3 million miles of circuits with associated switching and terminal facilities. Nearly 100% of these services and systems are leased. Consequently, lease costs comprise the great majority of the funds requested in FY 1985 to continue to operate and maintain these vital communications services.

The NASCOM Network is a global system interconnecting NASA's foreign and domestic tracking and data acquisition stations, launch areas, and mission and network control centers. NASCOM provides the operational communications support for all flight projects. During FY 1985, NASCOM will be reduced in size in

concert with the ground network stations closures. The remaining stations will be served by a Time Division Multiple Access (TDMA) system using advanced digital techniques which allow the effective communications bandwidth between any transmit/receiving connections to be adjusted to meet the dynamic communications workload. Also in FY 1985, use of fiber optic cables for high data rate distribution within the Goddard Space Flight Center (GSFC) will be extended to support the Space Telescope, Spacelab, and Landsat missions.

Program Support Communications (PSC) are those circuits and facilities used for the programmatic and administrative operations at all NASA Centers and Headquarters. These services include the facsimile, teleconferencing, logistics, and routine computer-to-computer interfaces.

MISSION CONTROL

The Mission Facilities Implementation Program provides the systems capability to command and control NASA's unmanned scientific and applications satellite program through Payload Operations Control Centers (POCC's) and related Mission Support Systems (MSS) which receive, process, and display spacecraft telemetry data and transmit commands. Currently, four control centers monitor and control some 10 spacecraft. Funds are required in FY 1985 to operate these control centers and supporting facilities for the control of on-orbit missions.

Emphasis will continue on the development of a control center for the Space Telescope. Major software developments underway for several years should be essentially completed in FY 1985. This software, consisting of some one million lines of code, manages the major operational activities of the mission including spacecraft and subsystem health and safety pointing the observatory at selected sources, pointing the user antenna at the TDRS, conducting mirror surface calibrations, and focusing the mirror itself.

Also included in the FY 1985 request are funds for modifications to the existing Multisatellite Operations Control Center (MSOCC) for control of the upcoming Gamma Ray Observatory (GRO) and the Cosmic Background Explorer (COBE).

DATA PROCESSING

Two separate activities are funded within the Space Tracking and Data Systems Data Processing Program. These include processing of bulk data acquired by the low Earth orbiting spacecraft for both scientific and applications, and real time computation support of mission operations which includes orbit and attitude determination and command management. Included in this request are funds to complete the system replacement for the major computational elements. Large data processing systems at the Goddard Space Flight Center (GSFC) provide support to missions currently in orbit and in the planning stages. The majority of the data processing funds requested in FY 1985 are to continue the

maintenance and operations of these systems.

In FY 1985, telemetry data processing support continues for the ongoing free flying NASA spacecraft such as the International Sun Earth Explorer (ISEE), Dynamic Explorers (DE), and the Interplanetary Monitoring Platform (IMP). Planning, systems implementation, and testing will continue for support of new missions such as COBE, GRO, and Space Telescope, future Spacelabs, the ASTRO series, Earth Observations Missions, and Sunlab. Experience gained in supporting the first Spacelab mission and the increased workload based on Spacelab mission requirements dictate the Spacelab Data Processing Facility augmentation.

ADVANCED SYSTEMS

For FY 1985, we are requesting a total of $15.3 million for the Advanced Systems Program. This program is a small but critically essential portion of the Space Tracking and Data Systems Program which performs studies and technological developments needed to aid our planning and to assure more efficient and cost effective mission support in the future.

The rapid advances taking place in telecommunications and computer technology must continue to be examined for application to future program needs. For example, microelectronics technology, especially for computer applications, is being applied beneficially to virtually all functions including tracking, telemetry, communications, mission control, and data processing. Studies and developments are needed to extend our spacecraft-to-ground telecommunications capabilities to multiple bands of frequencies up through K-Band. Optical technology is also being investigated for use in communications with spacecraft and is already in use for ground data transfer at several locations.

Application of such developments allow for reductions in future spacecraft weight and power, while increasing the amount of data that can be acquired and distributed from spacecraft at great distances. These developments also improve our ability to operate under ever increasing conditions of radio frequency interference and crowding of the frequency bands.

CONCLUSION

In summary, we are in a state of transition as we change from our traditional way of providing mission support. Initiation of this new era of operational support for flight programs through an operational Tracking and Data Relay Satellite System (TDRSS) and replacement of the traditional Ground Network in the primary support role for low Earth orbital missions, and to enhance and consolidate the Deep Space Network (DSN) support for planetary missions will certainly make FY 1985 a challenging year.

The launching of two additional Tracking and Data Relay Satellites and the completion of required testing will bring the TDRSS to full operational capability. The emphasis on the TDRSS service

contract will shift from development and spacecraft production to operation of the satellites and operations and maintenance of the ground terminal.

The requested funding level of $811.0 million for our Space Tracking and Data Systems Program budget provides the minimum resources necessary to meet all of our support requirements in this time of transition and to bring the TDRSS to its full operational capability.

Mr. Chairman and members of the subcommittee, this concludes my statement. I appreciate this opportunity to meet with you to discuss NASA's Space Tracking and Data Systems Program. I urge the full support of the subcommittee of our FY 1985 budget request.

Thank you.

SPACE TRACKING AND DATA SYSTEMS PROGRAM

FUNDING REQUIREMENTS (IN MILLIONS OF DOLLARS)

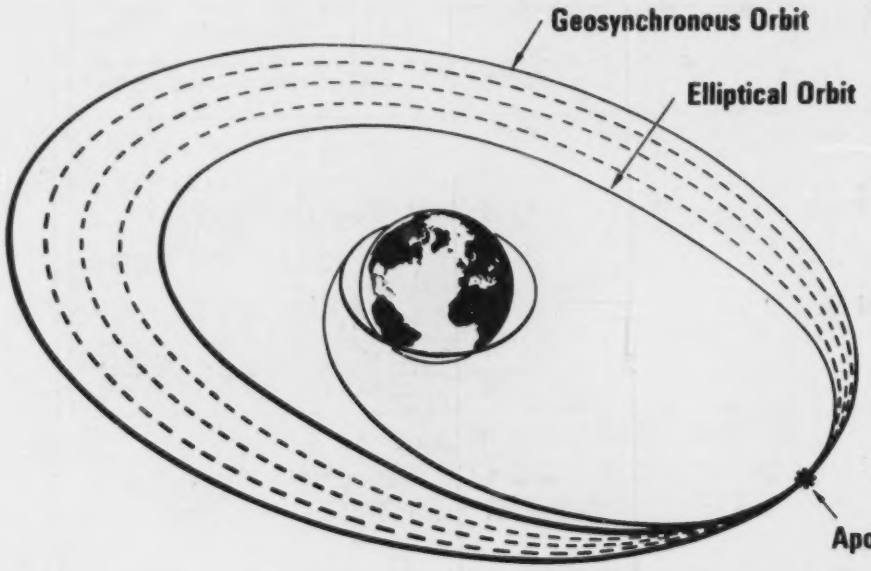
FY 1985 BUDGET REQUEST

SPACE FLIGHT CONTROL AND DATA COMMUNICATIONS	
• SPACE NETWORK	$ 386.5
• GROUND NETWORK	223.6
• COMMUNICATIONS AND DATA SYSTEMS	185.6
SUB-TOTAL	795.7
RESEARCH AND DEVELOPMENT	
• ADVANCED SYSTEMS	15.3
TOTAL	$ 811.0

NASA HQ T84-941B
2-9-84

FIGURE 1

TDRS-A MISSION RECOVERY



NASA HQ TC84-007(1)
1-13-84

FIGURE 2

TDRS-A RELAYED LANDSAT PHOTO OF SAN FRANCISCO AREA

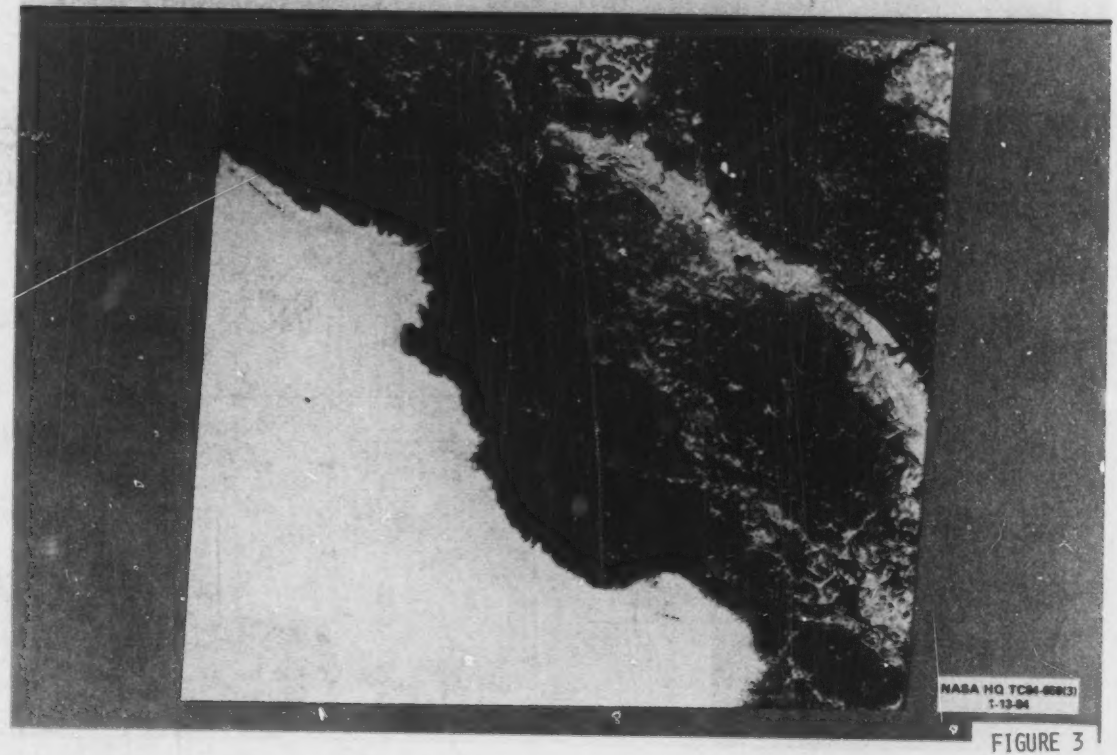
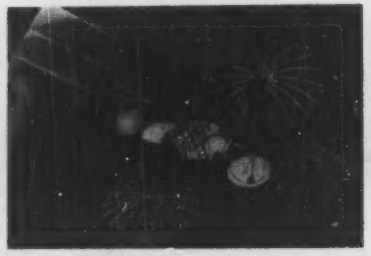
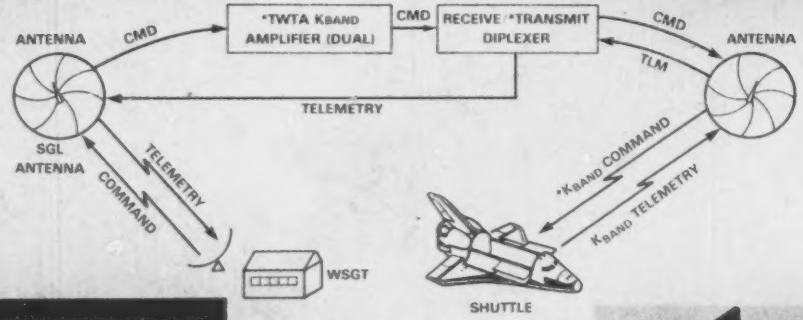
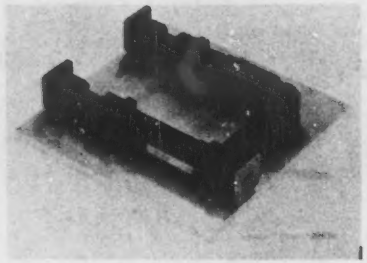


FIGURE 3





*MALFUNCTIONING AREAS/LOSS OF CAPABILITY



NASA HQ TC84-774(3)
1-17-84

FIGURE 4

GSTDN BASELINE STATION OPERATIONS TERMINATION PLAN

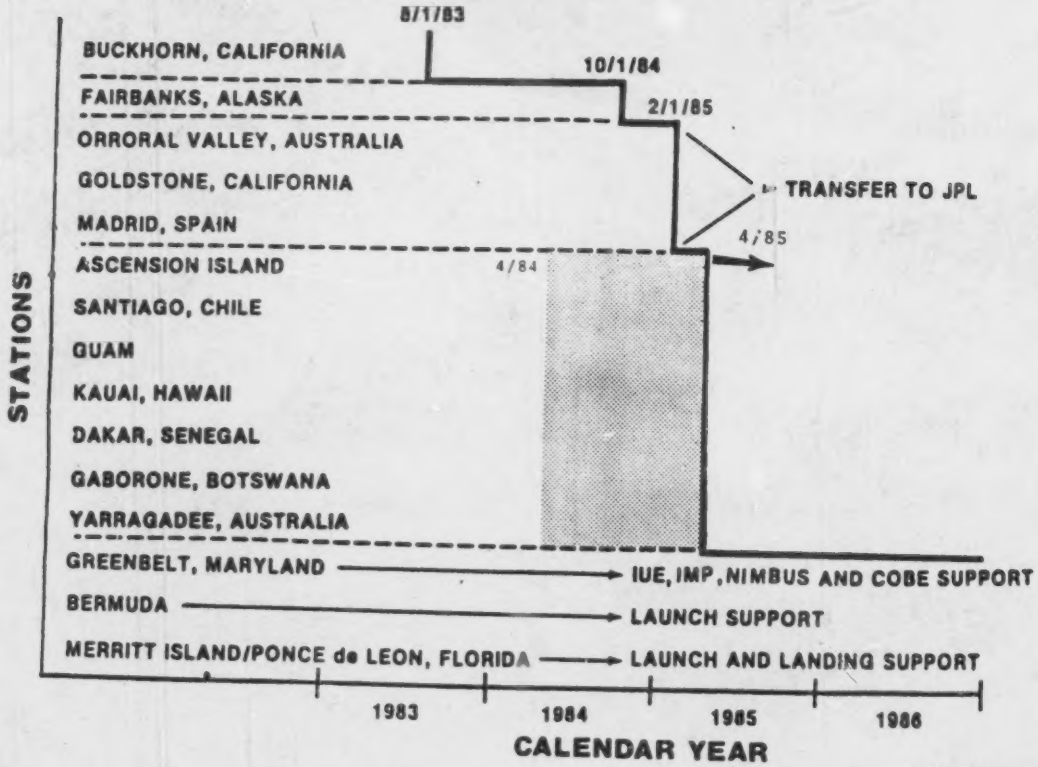


FIGURE 5

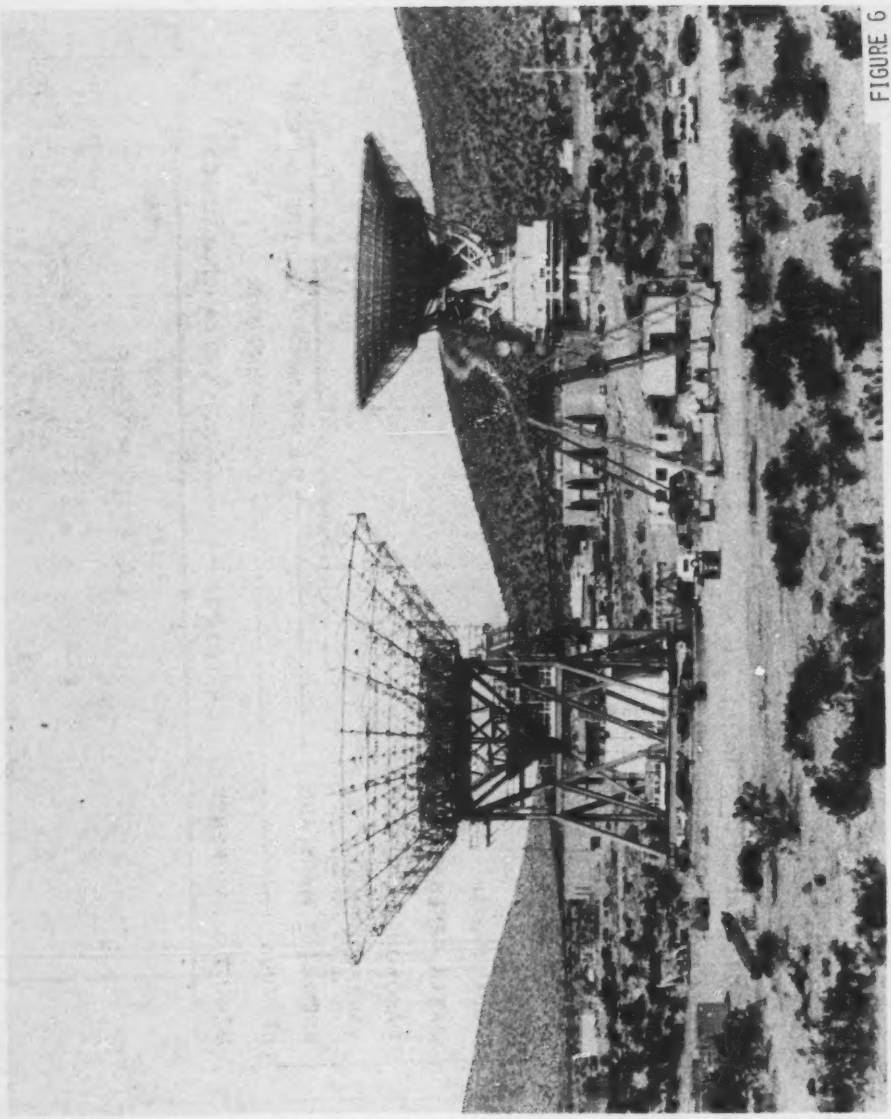


FIGURE 6

1989 VOYAGER/NEPTUNE & GALILEO SUPPORT CONFIGURATION

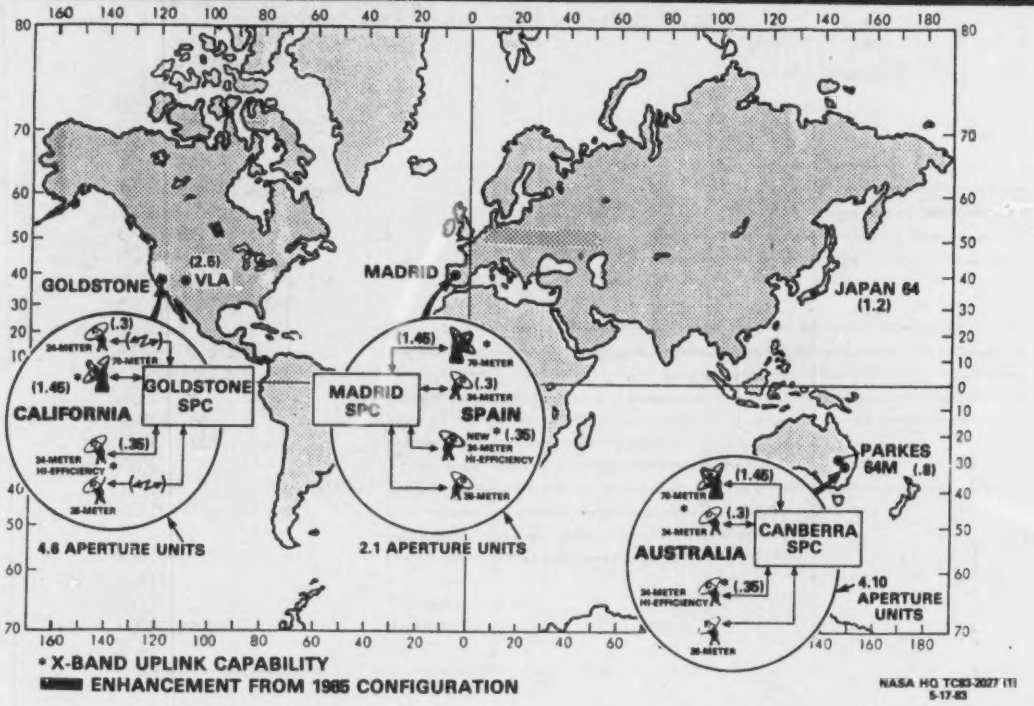
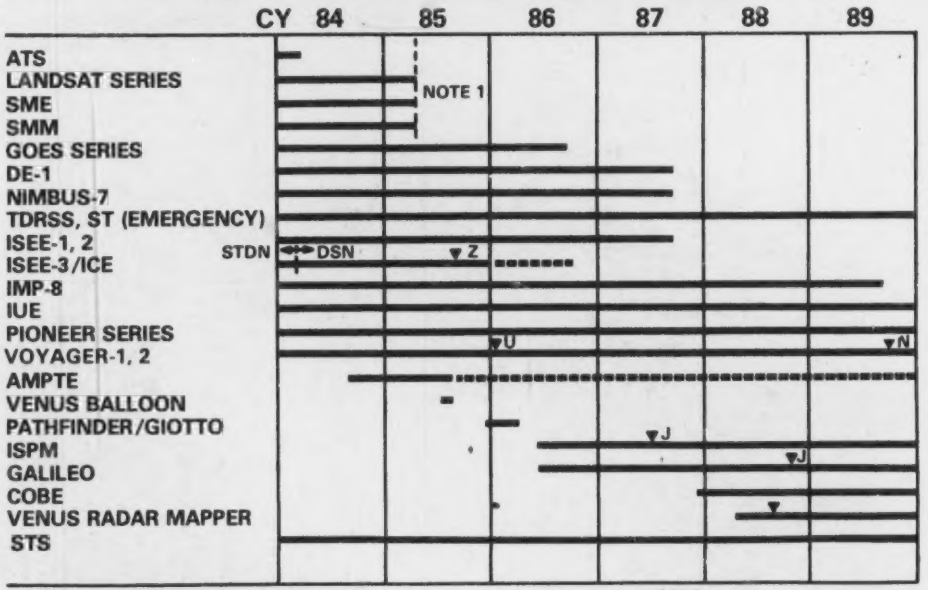


FIGURE 7

GROUND NETWORK
MAJOR MISSION SUPPORT PLANS



NOTES:

1. BEGIN FULL SUPPORT BY TDRSS.
   STDN STATION CLOSURES:
   ASCENTION, GUAM, HAWAII, SANTIAGO
2. STS LAUNCH AND LANDING SUPPORT CONTINUES AFTER TDRSS OPERATIONAL

LEGEND:

▬▬ SUPPORT MAY EXTEND

▼ ENCOUNTER (J – JUPITER, V – VENUS, U – URANUS, Z – GIACOBINA ZINNER)
N – NEPTUNE

NASA HQ T82-1223(1)
REV. 2-9-84

FIGURE 8

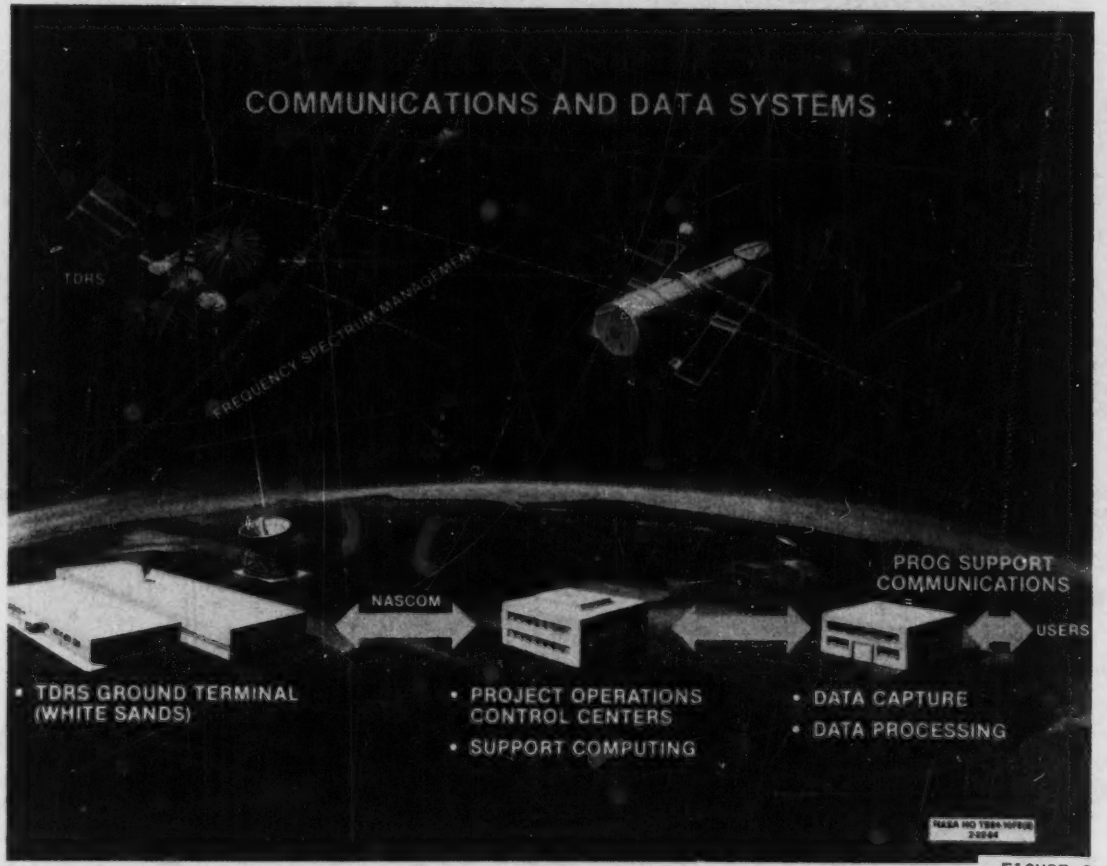

COMMUNICATIONS AND DATA SYSTEMS
TDRS
FREQUENCY SPECTRUM MANAGEMENT
NASCOM
PROG SUPPORT COMMUNICATIONS
USERS
• TDRS GROUND TERMINAL (WHITE SANDS)
• PROJECT OPERATIONS CONTROL CENTERS
• SUPPORT COMPUTING
• DATA CAPTURE
• DATA PROCESSING

FIGURE 9

Mr. VOLKMER. Thank you.

I recognize the gentleman from New Mexico.

Mr. LUJAN. Thank you very much, Mr. Chairman.

TDRSS satellites are working pretty well except for those small items that you told us about. How about the receiving station? Is that pretty much what you expect? Is it moving along pretty good?

Mr. ALLER. Yes, sir. I think we demonstrated with the Spacelab mission back in November and December, late November, early December, the functioning of that station. The results were we had, as I recall, about 155 orbits to support on that mission and the ground station and satellites supported 99 percent of the time it was requested.

Mr. LUJAN. What about the other 1 percent?

Mr. ALLER. The other 1 percent which we did not support were results of either late acquisition of the shuttle as it passed over or problems at the ground station itself.

Mr. LUJAN. It just was not received?

Mr. ALLER. We were just not——

Mr. LUJAN. Or was it received someplace else?

Mr. ALLER. No; it was not received at all. In other words, instead of a 45-minute pass perhaps we provided 35 minutes on that pass. The ground station itself, as you know and as far as I am aware, is the most complex ground station in the world. It is very highly automated and I think for this point in time in our development we have learned a great deal, and it is functioning just about as we expected at this point.

Mr. LUJAN. In closing some of those ground stations that you are going to close, are there any problems that you anticipate with those?

Mr. ALLER. No, sir.

Mr. LUJAN. They are going to be later of course because we did not get operational——

Mr. ALLER. As far as closing the stations, we have done a lot of that already. We have closed several stations around the world, Quito in South America, one in England. We will not have a problem in closing the stations. The problem we will have is having the TDRSS in orbit fully operational so that we have that available to close those ground stations.

Mr. LUJAN. I was thinking of any local problems.

Mr. ALLER. No, sir, we do not expect any. Some of those stations will be transferred. For instance, the Chilean Government is interested in a site at Santiago. We are going to transfer the Alaskan site to NOAA; the Hawaiian site DOD is interested in. We do not anticipate problems with those closures.

Mr. LUJAN. Is it not expensive to keep them open because of the delays?

Mr. ALLER. Operational costs will continue for those sites. That provides the support for low Earth orbiting spacecraft. Those stations are operated 24 hours a day nearly 7 days a week. That provides the support for all the unmanned satellites that are in Earth orbit. We have no choice but to maintain a system that is operational.

Mr. LUJAN. How much longer time are we going to have to operate those?

Mr. ALLER. That is under evaluation. We had planned to close them in April of next year, as I said. With the latest IUS schedule that will be slipped a few months due to the launch impact on TDRSS, and I anticipate at this time 4 to 6 months' delay.

Mr. LUJAN. It is not significant?

Mr. ALLER. No, sir.

Mr. LUJAN. Tell me something about this whole business of financing of TDRSS. People come in and tell me just to get it off the budget. It is still costing the Government the same amounts of money in leasing that it would have cost to develop it. We are still paying the same kind of costs. I guess what brought that to—up to the surface was Western Union getting out and receiving their share that they had invested and it really was not ever Western Union money, it was money that they had been paid anyway by the Government. Can you shed some light on that for me and why it was done that way?

Mr. ALLER. Well——

Mr. LUJAN. Is it a good deal for——

Mr. ALLER. As I understand it, back in 1976 when the program was initiated it was felt that the TDRSS technology was standard communications satellite technology. I think we have demonstrated that is not the case. It is a highly technological system that we have put together. But despite that there have not been major changes in the spacecraft itself nor the spacecraft design. There have been some additions from an operational standpoint, but the spacecraft itself has not undergone a major redesign effort. At that time, therefore, it was determined that this could be a lease program in the same nature as we lease Domsat satellites every day for our NASCOM circuits, for instance, and as such the Government decided, Congress and NASA decided that the program development could be financed through the Federal financing [1] and that NASA would pay for the services when those services were initiated through lease payments similar to the way we are paying for the communications satellites that fly by leasing those services.

Mr. LUJAN. Isn't there a difference there in that we might be sole users for TDRSS while we might not be for communications satellites?

Mr. ALLER. Yes, sir, there is a difference. Also when it started it was a shared program, a so-called shared program in that there was a commercial aspect and a Government aspect. A year ago when we went through the contract modification the Government arranged for the rights to the entire spacecraft and the use of the system to eliminate the conflicts that we were experiencing in the control of the system operationally and in the development because of the interest of the commercial aspects of the program. Those elements of the program are still on board the spacecraft. However, the use of the spacecraft is fully dedicated to the Government at this time.

Mr. LUJAN. And is it true that Western Union got a big chunk of money back for pulling out as their interest in it, money that was not Western Union's money to begin with—in other words, it was a windfall for them?

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[1] To clarify, this should read: "through the Federal Finance Bank."

Mr. ALLER. Well, of course we deal through a company called Spacecom. They are our contractor and part of the negotiation for reformation was a settlement with the contractor that allowed for the commercial aspect of the spacecraft both in its development and in denying its use over the 10-year service of the vehicle, and that use would have included leasing those 12 transponders that were available on each satellite for commercial use and revenue. So the settlement considered that in establishing the settlement with Spacecom.

Mr. LUJAN. But did the stockholders, the three companies in Spacecom, ever put any of their money into TRDSS, or was it all Government money and they ended up with a bonus?

Mr. ALLER. The Government is the underwriter for the loan, and the only money that we track from the Government standpoint is that loan. That is the vehicle that we have—we are responsible for paying off.

Mr. LUJAN. But you give them the money to make the payment for the lease?

Mr. ALLER. No, sir. The money flows from the Federal Finance Bank to the contractors. Our payments back to the bank, which began last August, go directly from NASA to the Federal Finance Bank.

Mr. LUJAN. Has Spacecom put out any of their own money for the development of TDRSS?

Mr. ALLER. I have no way of directly knowing what the contractors have put in the way of funds into the program. The only visibility that the Government has is directly with its contract——

Mr. LUJAN. I understand, but you work with them. It would seem, you know, that the financial arrangements would be known to NASA. I understand that your responsibility is just the money that the Federal Government spends for leasing the facility.

Mr. ALLER. Yes, sir.

Mr. LUJAN. But doesn't NASA have any idea about the other financial arrangements?

Mr. ALLER. It would be conjecture on my part, sir, for any response.

Mr. LUJAN. Who in NASA would know?

Mr. ALLER. NASA has no direct data related to the contractor's investments in the program. The only data we have records of is that data that is associated with our contract and the amount of the loan with the Federal Finance Bank.

Mr. LUJAN. Well, so that your part was only in saying we are now going to buy out that interest that was previously dedicated for commercial use and here is what we are going to pay you for it, and what you do with it is none of our business? If Western Union wants to bail out because they have got other fish to fry somewhere, that is their business?

Mr. ALLER. Yes, sir. In the settlement the amount that went to allow for the services that would have been retrieved over the 10-year service was paid to Spacecom and the use they made of that or the three owners of Spacecom at that point was indeed their business.

Mr. LUJAN. I can't believe that NASA would just say this is our responsibility and we are just going to look down this lane because

that is our responsibility and how you arrange your financing, how these things come about, we care nothing about.

Mr. ALLER. Sir, we control the amount of spending on the program that the Government is responsible for through our contract. The contract controls the level of borrowing that they are allowed to borrow to and it controls the overall funding that the Government will put into the program. That is what we control.

Mr. LUJAN. I understand that. I understand that that is your responsibility. But if I were going to lease a building, that I want somebody to build a particular kind of building, I would say I am going to give you so much money every month for lease on this building. Yet that building is a building of a type, and of equiment in there, that has never been built before, it would seem to me that I would look to the contractor to see if that contractor was capable first of all of doing it. And apparently you determined that they were. But in addition I am depending on that: do you have the money, have you got the line of credit? I am going to demand a surety bond to see that it is built exactly like I want it, because no other building like it has been built before. And it is rather strange to me that NASA would be just concerned with how much rent are we going to pay every month without going into the other financial aspects.

Mr. ALLER. Well, I think the fact that we underwrote the loan, originally it was determined that the only financing available would be on a Government-assured loan.

Mr. LUJAN. Why would we—I can't quite understand why we would say well, we will guarantee your loan, we are responsible for it, you go borrow the money and if you don't pay it back, we will pay it back. That is what underwriting means. It seems like why we wouldn't build it ourselves and then it would be ours when the whole thing is completed. That is——

Mr. ALLER. Well, that gets back I believe to your previous question, that in the mid-1970's it was felt by NASA management that this program fell in the basic technology of communications satellites and that it could be implemented as a matter of fact at that time commercially. It was determined that banks would not step up to the R&D nature of this type of program and it was then determined the Government would guarantee the loan.

Mr. LUJAN. But by then the bus was headed in that direction and it was too late to turn it around.

Mr. ALLER. Well, it proceeded in that direction and has since. I think your previous statement is correct, that from the Government standpoint the cost to the Government is basically the same in either case.

Mr. LUJAN. Thank you, Mr. Chairman.

Mr. VOLKMER. The gentleman from Pennsylvania.

Mr. WALKER. Thank you, Mr. Chairman.

What is the total budget impact on your program of the IUS anomaly?

Mr. ALLER. The 1985——

Mr. WALKER. In the 1985 budget.

Mr. ALLER. Budget impact. We have previously answered a question from the Chairman in that regard indicating $57 million in the 1985 budget as a result of the IUS impact. We will have to

revise that number due to the IUS—latest IUS slip that I mentioned in the testimony and we are presently evaluating what increase that will be.

Mr. WALKER. Does that include—it is my understanding that for instance since you are not going to fly the satellite quite as soon as expected, there is now some redesign work going on, some new additions being put on it, does the figure you are giving us include those items?

Mr. ALLER. No, it does not. The redesign going on is to correct the problem I discussed during the testimony. That is not a significant impact as we see it at this time to the Government. The costs of delay are involved with keeping the ground stations around the world open an additional time until we can successfully obtain operational capacity and the additional manpower necessary at the White Sands ground station in a test configuration before it becomes operational.

Mr. WALKER. There are no add-ons taking place with regard to the communications technology, all the work being done on satellite relates directly to the IUS?

Mr. ALLER. The work being done does not relate to that totally. We are modifying a C-band system aboard the satellite. That is being paid for by the DOD. We are modifying it such that it can be used both domestically as well as between the United States and Europe. That modification is ongoing. The other modification is whatever fixes we determine are necessary relative to the diplexer, and that I must say is typical of any program of this nature. Any problems you find, and you expect them, when we find problems we try to understand those problems and fix them for the follow-on vehicles.

Mr. WALKER. I do not necessarily disagree with that. I am trying to get at what that $57 million that you are mentioning means. In other words, does that include those fixes that you are talking about and does it include the amount of—well, obviously it does not include the amount of money that DOD is spending, but that is in fact additional add-on cost to the Government as a whole?

Mr. ALLER. It is an add-on in 1985 and it is a mixture, sir; $24 million of that is the station cost to keep the stations open for a 6-month period in 1985. The $33 million is made up of both costs that have been delayed out of 1984 because of the delay, including some launch vehicle costs as well as additional costs associated with those fixes associated with the IUS slip. We have had some costs associated with that slip itself including more money to fix the IUS.

Mr. WALKER. If that——

Mr. ALLER. Excuse me, let me answer the other part. But none of the problems that we have experienced on the satellite are incorporated in that. This budget was put together last summer and those failures occurred this fall. We have not included any of those costs.

Mr. WALKER. Where is the money going to come from for the fixes that are not included in the $57 million figure? Where in the budget are we going to take care of that?

Mr. ALLER. We do not have the fix in hand for the space problem. However, it will be in this particular year 1984 that we will

have to establish that fix and those costs we feel at this time we have covered within the scope of the program.

Mr. WALKER. So you will not have to come back for a supplemental on that?

Mr. ALLER. I can almost guarantee that we will not have to come back for a supplemental in 1984 for those fixes.

Mr. WALKER. Thank you, Mr. Chairman.

Mr. LUJAN. Just a followup question. You said that, at the time, it was felt that that was the best way to go, the lease arrangement. In retrospect, and Monday morning quarterbacking is pretty easy to do, but I am directing that question so that, what about future programs—in retrospect do you think that was the best way to do it? Our basic feeling is that that was a way for NASA to get it without going through the appropriations process. It was back-doorring, and now we are paying for it in the rent. So with that unbiased view of the whole question, back to my original question, in retrospect do you now think that, with what we know today that we should have been going into that kind of arrangement?

Mr. ALLER. I feel like Joe Gibbs, why did he call that pass in the first half. He said he wanted to go for points.

Mr. LUJAN. The purpose of my question is for future—you know, did we learn a lesson that maybe we shouldn't or maybe we should in the future?

Mr. ALLER. We have learned a lot of lessons, Congressman. I certainly hope we have learned a lot of lessons and I don't think the book has been written on TDRSS yet. For one thing, I think the program itself has worked very well considering the complexity of the program and it is working well.

Mr. LUJAN. Agreed.

Mr. ALLER. I believe NASA proceeded down a path that they felt would provide the TDRSS earlier. I think the major difficulty in the TDRSS program has not been the contract nor the financing. I think what the major difficulty in this type of program is is the fact that we were bringing TDRSS, a brandnew system, on line, we were bringing shuttle, a brandnew system, on line and we are bringing IUS, a brandnew system on line.

Mr. LUJAN. I am just talking about the financial aspects of it.

Mr. ALLER. I would like to make the point I don't think the financial aspects would have ever been questioned had the overall cost to the Agency not increased, and the costs to the Agency basically have increased due to those delays of bringing those three elements together simultaneously and the fact that the interest costs during that period reached a very high rate as you well know. There is nothing wrong with a lease service. We do it every year. We are leasing satellites every year. I think the major concern when you go into a lease-type contract is that the configuration of the device you are leasing, whether it is a computer, whether it is a satellite, whether it is a building, that that configuration be understood, and for that reason I think in hindsight there may have been different routes to go. I don't think in the end the cost to the Government would have been much different nor would the system that we have, have been much different.

Mr. LUJAN. Thank you.

Mr. VOLKMER. Mr. Aller, I would like to get into something, get back into what the gentleman from New Mexico and the gentleman from Pennsylvania talked about in more detail. I would like to get into TDRSS itself. First I would like to ask, the fact that the IUS didn't perform properly and that the TDRSS was tumbling through space, did that have any effect in your opinion on either the diplexer or amplifier?

Mr. ALLER. No, sir, I think it had no effect on either of those.

Mr. VOLKMER. So those basic defects that have occurred were caused by other causes?

Mr. ALLER. Yes, sir.

Mr. VOLKMER. And malfunctions that originated from either design or production procedures in the formation of those instruments; is that correct?

Mr. ALLER. That is what we now believe, sir.

Mr. VOLKMER. Now as far as the amplifier, it is my understanding from what I had heard before that the problem was with the traveling wave tube. Now I understand you are saying it is with the energy source.

Mr. ALLER. The device is commonly called a traveling wave tube. It consists of a tube, a power device that drives that tube, and during the time of the problem I am sure those of us in NASA referred to it as the TWT failure. The tube itself, of course we can't get our hands on this device. The telemetry we have actually are measurements of the tube itself and that is where we measured the failure. However, we feel the failure that has occurred is in the power device that supplies the power to that tube. It is actually a 2,000-volt power supply and we think in the area of that high-voltage converter we are having some arcing and therefore we do not think the tube portion of the TWTA has failed but rather the power supply to the tube.

Mr. VOLKMER. What has been done to make sure it doesn't happen in the next TDRSS that goes up?

Mr. ALLER. We are in the process of test and I am unhappy to say right now we do not have a final fix on the correction on that power supply. We have several devices in test. We have been conducting tests since November. We have had similar failures on the ground. We have found the arcing source on one of those failures and we are presently analyzing through further test what will necessarily be done to that, probably the high-voltage converter device itself.

Mr. VOLKMER. In the diplexer as I understand it, the little screws that are in my glasses were screwed perhaps too far——

Mr. ALLER. We have opened diplexers that we have taken off the vehicles that are on the ground and back at the manufacturer and we have found contamination of the sort that could result from procedures used in tuning a diplexer that would have run the little screw down too far, hit the top of the resonator and then backed off in the tuning procedure, and we have demonstrated that the power loss was getting through that diplexer can be accomplished in many ways through contamination in this resonant filter, and that is why we feel by changing some of the materials in the diplexer and having very tight quality control on the tuning procedure itself we can clarify that problem.

Mr. VOLKMER. What you are telling me is we still—have you clarified the problem as far as the diplexers?

Mr. ALLER. We have clarified—I believe we have, sir. We are making that presentation to the Administrator tomorrow night, and I believe after tomorrow night we will have approval to proceed with that correction.

Mr. VOLKMER. What you are telling me is—I have been one of those who believe that the problem with getting the IUS to where it would function is the only thing holding up putting up the other two TDRSS's. You are telling me that even if we had IUS ready to go we still wouldn't be putting up the second TDRSS?

Mr. ALLER. If we had it ready today we would have a problem. The construction schedule allows us to meet the previous schedule, December of this year, with a fix or with a very severe test program on the power amplifier that runs it through an environment that is far more severe than it sees in flight, and having run it through that environment we feel we could qualify the flight. However, we are continuing to evaluate through test a similar power supply on the ground.

Mr. VOLKMER. What you are telling me is that any delay perhaps after the flights that were scheduled for December and early 1985 on TDRSS, it passes those, which you are telling me now early 1985, middle 1985, they would be IUS problems but right now the delays that we are under are not solely IUS? These were supposed to be up last year.

Mr. ALLER. We have a problem with the spacecraft, too; yes, sir. The spacecraft is under the umbrella.

Mr. VOLKMER. That is what I wanted to get to. Can you tell me what the payment schedule to the FFB is on the TDRSS? We have a payment here of 300—I have it in here. If you can't give it to me here I would like to have it for the record.

Mr. ALLER. I can give it to you for these 2 years.

Mr. VOLKMER. I would like to have it as far as you can give it for future years, also. Give it to us and then give it to us in the record. I would like to have that.

Mr. ALLER. Allow me to give it to you for 1984 and 1985, and I will give it to you in the record for the following years.

In 1984, it is $185 million; and in 1985, it is $210 million. And I will supply for the record for the remaining years.

[The information follows:]

FFB payments as reflected in the fiscal year 1985 budget request

Fiscal year:	*Millions*
1983	$29.0
1984	185.3
1985	209.9
1986–92	[1] 226.2
1993	168.6

[1] Per year.

Mr. VOLKMER. Has that continued to increase?

Mr. ALLER. No. It increases slightly in 1986 because we will pick up a full third loan, the third loan being the one that ends this year. And I think it is a slight increase in 1986, but basically it is close to the $210 million.

Mr. VOLKMER. Were those payments depending on schedule payments, or are they based on in the agreement the service performed by the contractor?

Mr. ALLER. Yes, sir. Those payments were—the Congress permitted us to initiate those payments in August based on the fact that the first spacecraft had been delayed, and we got it into orbit and demonstrated, such as with the Landsat support that we obtained in July, and the shuttle support, that we should initiate payments that had been proposed to us, and we initiated that payment last August. We had another one in October, and we will have a smaller one in March of this year.

Mr. VOLKMER. Can you tell me—we have got—except for the problems with the diplexer and the amplifier, are there three completed now or four?

Mr. ALLER. Spacecraft?

Mr. VOLKMER. Yes.

Mr. ALLER. There are two on the ground that are basically complete, two and three. Four, a major portion of its payload segment has been completed; and five and six are in various stages of assembly.

Mr. VOLKMER. When is the completion date for the final one?

Mr. ALLER. The final completion date is presently near the end of 1985 or the beginning of 1986, somewhere in that timeframe.

Mr. VOLKMER. And for what period of time are the payments scheduled out? Period of years?

Mr. ALLER. It is over a 10-year period. So our first major payment was in October of 1983. The last payment, I believe, is in 1992.

Mr. VOLKMER. Are there any other problems that you can see with the spacecraft, other than the diplexer and the amplifier, that you know went wrong; anything else that——

Mr. ALLER. During our recovery when we came out of the tumble and then we were maneuvering with the small thrusters, we failed—we have a redundant set of thrusters, and one side failed due to the fact the hydrazine overheated and actually we think blew a line just forward of one of the thrusters, so we had to close down the manifold on that side or we would lose the hydrazine.

We had a roll thruster fail for, we think, the same reason—this device overheating during the early phases of the recovery. So we had the vehicle work with 11 of the 24 thrusters remaining.

We don't see that as a problem. We can dump our momentum wheels with the remaining thrusters, move from one location to another carefully with the remaining thrusters. We have one out of four gyros fail, we have plenty of redundancy on the gyros. Those are the only problems that I am aware of at this time on the vehicle.

Mr. VOLKMER. The changed amount that you mentioned, like on the C band, which is being paid by DOD. What changes are being made on the spacecraft that NASA is instigating and paying for?

Mr. ALLER. At this point in time, there are no new changes over the vehicle that is in flight that the Government has directed other than the C band. There is a change in the housing, the thruster housing that the contractor implemented himself. He actually converted the housing back to a housing more similar to the

FLTSATCOM so it would provide a little better thermal protection to the thrusters themselves.

I am not aware of any other changes to the spacecraft.

Mr. VOLKMER. Now, for 1984, you need no additional funds. But for 1985, over and above what is presently in the budget, due to the fact that we are not going to put the second and third TDRSS up until later on, what impact does that have on the current request to Congress?

Mr. ALLER. Well, sir, the impact will be determined when the final schedule and the manifesting—it is really a combination of when the shuttle can manifest the IUS and when the IUS will be available to us at the cape. We estimate our impact is about $5½ million a month, and so it depends on how many months we slip will be the impact on the 1985 budget.

Mr. VOLKMER. Now, is there any consideration given to any other alternative means of putting a spacecraft in orbit other than the IUS?

Mr. ALLER. The only capability that exists in hardware that has been flown, that I am aware of, is a Titan Centaur combination, and I am told that combination would not be available with the reconfiguration of the pad at the cape, which would have to be reconfigured to do that in less than a 3-year timeframe.

At one time, when I came into the program in about 1979, there was a Titan Centaur backup, and that was eliminated from the program based on the fact at that time it was felt the shuttle schedule would support the schedule we were on.

Mr. VOLKMER. So right now we do not have an alternative?

Mr. ALLER. There is no alternative upper stage to fly within the shuttle and to support TDRSS.

Mr. VOLKMER. What actions are you taking to improve and expedite the processing of data generated from scientific missions for dissemination to the scientific and industrial community?

Mr. ALLER. Well, that is in the data processing piece of our budget, and the activities there in 1985 include increasing the capacity of the spacelab data processing facility. That is the facility that I had indicated performed so well during the spacelab mission. The requirement on that facility is to receive the spacelab data. As you recall, that data gets up to 50 megabits per second, a very high data rate; and today what we call data capture or quality check on the data, record the data, and do some initial processing of it and deliver it to users. That turnaround cycle is 30 and 60 days.

Some of the users take the data in 30 days. We do a little more processing and get the rest out in 60. We met that schedule. We are, in 1985, upgrading that facility because of the mission model of spacelab missions. We build those facilities on average data rate. In other words, we don't get 50 megabits continuously; it varies during the mission.

The programs we are looking at in the future have higher data rates and they are being flown more often. They are asking us to accelerate the turnaround from 60 to 30 days. That is part of the work we are doing in the 1985 budget. We are completing the Space Telescope Payload Control Center and data capturing involved in that program in 1985. We are doing additional work on the GRO program. We are implementing control facilities for that.

And we are completing a major computer upgrade that we have had ongoing at Goddard for several years that will allow us to do all the orbital computation, the attitude orientation and the command generation for all programs at the Goddard Spaceflight Center.

Mr. VOLKMER. When is the Deep Space Network to be completed?

Mr. ALLER. When it is to be completed?

Mr. VOLKMER. Yes.

Mr. ALLER. The program that we have ongoing is to upgrade the consolidation of the three sites with the lower orbital stations at that site. It is to provide the tying in of all the antennas at that site. And that program, the final implementation of the program growth from 64 to 70 meters is in the 1986 budget—will be in the 1986 budget—and that completion is projected in about the 1988–89 timeframe.

Mr. VOLKMER. But funding will be completed, in other words, in 1986?

Mr. ALLER. The C of F funding necessary to provide the extension on the large antennas will be in the 1986 C of F program.

Mr. VOLKMER. As you know, the President recently signed an Executive order designating the Department of Transportation as lead agency for the commercialization of expendable launch vehicles.

The question I have is: Does NASA presently have sufficient capability to support communication and data needs for a commercial ELV industry?

Mr. ALLER. I believe, sir, that is just being initiated and developed. We don't, in my area, have a great deal of visibility into how that is proceeding. However, I believe we have ample capability to support launches and would not anticipate a more severe problem than we have today, and we support all launches, I would presume, on a reimbursable basis to NASA for whatever communication support we provide.

Mr. VOLKMER. Does your office participate in any studies as to what charges should be made and a policy decision as to how those charges should be made?

Mr. ALLER. We have reimbursable policies for all of our services in place, and I see no reason that those policies wouldn't apply as they are for the commercial launches.

Mr. VOLKMER. Are those based on additive costs?

Mr. ALLER. Yes, sir.

Well, I should qualify that. For the ground network, it is basically additive costs. There is some surcharge, I believe, for non-Government use. And in the TDRSS program, the reimbursement policy is based on the time usage of TDRSS; basically, how many minutes you use the system is what you pay for. That is not an additive cost.

Mr. VOLKMER. That is just a user charge?

Mr. ALLER. Yes, sir.

Mr. VOLKMER. If the Congress should take your total budget and decide that, for one reason or the other, that this $811 million needs to be cut because of one or sundry reasons, whatever it may be, say, by $50 million, where do you anticipate you would make those cuts? Could you make them in the payment to FFB?

Mr. ALLER. Could I make them in the payment?

Mr. VOLKMER. Yes. Could you reduce the payment?

Mr. ALLER. Well, you know, it is kind of like the deficit, I guess. First of all, let me, if I may, remind you that I tried to emphasize the $811[1] didn't include our latest problem on the IUS schedule.

Mr. VOLKMER. Yes.

Mr. ALLER. However, in direct answer to your question, the way the loan works, the delay of payments to the bank are put on the next payment for next year, and we would then see a lump payment in the October payment for 1986 if we did not make the full payment in 1985.

Mr. VOLKMER. There's not too many other places that you can take away the payments. You are not going to close any ground stations down.

Mr. ALLER. Sir, our budget is basically built around the requirements of the spacecraft users, and each of the areas I described are active, very active in 1985, and I believe the flexibility that we have in the budget has long gone with our latest problem.

Mr. VOLKMER. Now, the services that your office handles, Space Tracking and Data Systems, usually you are basically used by all or most of all the NASA program offices; is that correct?

Mr. ALLER. Yes, sir.

Mr. VOLKMER. But the cost of the services are set out here to you and not to those offices?

Mr. ALLER. Yes, sir. They are in our budget, not theirs.

Mr. VOLKMER. Right.

Now, do you see any possible savings that could be made if we were to take those and say, no, we are not going to have them here, but we are going to put them in the offices so each of the offices can see how much they actually spend on those? Would you be able to save any money?

Mr. ALLER. Well, the way—we actually do require budgeting from program offices when they have unique requirements. If they require a site some place, a unique requirement, that we levy against the program as a specific program cost. In the situation where the Government, the country, has determined it needs a facility like a deep space net or a ground net for the low Earth orbiting, or a TDRSS system, or data systems, the costs of that system could not be borne by any one program.

We could take the annual coverage we have of all programs and somehow distribute the costs across. It has been the practice for years in NASA to provide the facility much like we provide a cape facility for launches, and base our charges on—our budget on those requirements. I don't—I would not see the advantage to you nor to us, and I certainly can't see how the costs would change, by distributing the various programs.

Mr. VOLKMER. The gentleman from Florida.

Mr. NELSON. Thank you, Mr. Chairman.

Let me ask you, Mr. Aller, is the fact of getting the TDRSS up into the correct orbit and how it gets up there—is that under your bailiwick?

Mr. ALLER. Yes, sir.

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[1] This should read "$811 million".

Mr. NELSON. I am very interested as to what was the reasoning that NASA used that it wanted a—the TDRSS booster is a solid rocket propellant, isn't it, the IUS?

Mr. ALLER. Yes, sir.

Mr. NELSON. Let me draw something here and hold it up. In the center is a ball. That means—that is the Earth. And right around that ball is the—that is the shuttle orbit around the Earth. And the TDRSS is going to be up in geosync, so it is up there at that level, 23,000—22,300 miles up. So you have to get a low Earth orbit up to geosync. So you have to go up there like that.

Now, the theory would be—I am very curious as to why NASA chose a solid rocket propellant. To get from this position in low Earth to geosync with a solid rocket propellant, you have to have just exactly the right amount of solid rocket propellant to get you where you want to go, because you can't turn off the engine. But with a liquid propellant, if you want to fly from there to there, you fly it, and then you signal it to shut off the engine, and you are right there. But solid rocket propellant, in order to get from there to there, you have to have exactly the right amount of propellant to burn out or you got to fly that thing in a circuitous route to get from point A to point B.

Why did NASA decide—and I must admit my question is hindsight now that we have seen this fail—it has delayed our future TDRSS's, delayed a big defense package, and there is no confidence there, so they canceled it this summer again. So what was the original thinking of wanting to have a booster that was a solid rocket when we had boosters that were liquid that had worked; there was a lot of track record on liquid boosters?

Mr. ALLER. I am not the one to answer that question. I am not well versed on the selection of the IUS as the stage to be involved in heavy lift to geosync.

Mr. NELSON. Who would be?

Mr. ALLER. I can give you my views of it, rather obscure views at the time. I believe you are absolutely correct that the Nation is in some difficulty in its solid technology to date. We have had, as you have pointed out, problems with NASA payloads. We have had problems with commercial payloads based on solid problems. As I understand it, DOD has some problems with their solids, also.

I believe, again, you are talking about hindsight. I think the technology of solids has been used for a long time. I should say, however, with the shuttle we have had quite good success with the solids aboard the shuttle.

Mr. NELSON. I sure hope so, because if they don't fire in sequence at exactly the same time, we are in a heap of trouble.

Mr. ALLER. Nevertheless, that is an example of that technology that is working well. The factor that the solid was easily handled, the factor that the technology was felt to be well in hand and easily handled in the environment of the shuttle, in the environment of the shuttle on the pad as well as in flight, the performance can be very nicely handled by guidance.

The problem of a solid is not a real problem in placing it where you want to place it. I think those were the factors involved in that determination.

Mr. NELSON. Was that an Air Force decision?

Mr. ALLER. I can't answer that.

Mr. NELSON. Who could?

Rather than take up your time—and I appreciate your position very much—why don't you just get somebody to answer that from NASA. Let me know what was NASA's original thinking, how much NASA was influenced by the Air Force. Was it an Air Force decision? Did Air Force strong-arm NASA into it, or was it a mutual, or what? I would like to know because it seems to me hindsight is a beautiful vision. But we need to understand what were our mistakes in the past as we make decisions for the future.

Mr. ALLER. Certainly. I will have supplied for the record a chronology of the decisionmaking.

Mr. NELSON. I appreciate that. And make it understandable. We get some of this stuff and it is nine pages—crisply, this, this, this. I would appreciate it.

Mr. ALLER. Yes, sir.

[The information follows:]

The Joint Air Force/NASA source evaluation board for IUS selected the two-stage solid rocket motor configuration over liquid propellant stage contenders because it offered the protential of reduced complexity and lower costs. The IUS was the only Shuttle upper stage under development at that time which could place 5,000 pounds into geosynchronous orbit as required by TDRS; therefore, the decision to launch TDRS on IUS.

Mr. NELSON. Thank you, Mr. Chairman.

Mr. VOLKMER. Mr. Aller has informed us that there is another slippage in the TDRSS. Instead of December of this year for the second one, we are looking at next year now, early 1985. And instead of early 1985 for the third one, we are looking at the summer of 1985.

Mr. NELSON. Then my question is all the more appropriate.

Mr. Chairman, that is bad news, but I am not surprised by virtue of the fact that the Air Force had to delay again on its program which it was using an IUS. And the Nation is going to suffer. We are suffering from what we can talk about, and we are going to be suffering from what we can't talk about in this meeting from a defense standpoint. But we are going to suffer from what we can talk about—about the fact that we are not going to have another TDRSS up there to help us with our space lab, and so on and so on.

Thank you, Mr. Chairman.

Mr. VOLKMER. I have no further questions. I want to thank you, Mr. Aller, and I would appreciate receiving the information as far as further payments to the FFB as they go out over the 10 years.

I thank you for being here today.

Mr. VOLKMER. Our next witnesses are Patrick A. Templeton, Associate Administrator for External Relations, along with Mr. Ronald J. Philips, Director, Technology Utilization and Industry Affairs, Office of External Relations.

Pat, welcome to the committee. Mr. Philips, your statements, which you have been so kind to provide us in advance at this time—Pat, I guess you will go first. The statements will be part of the record. You may either proceed with your statement or summarize. I do not think you can very well summarize the shortest statement we have had in all the authorization hearings we have had so

far. As soon as you have finished, Mr. Philips may proceed with his. Your statement also will be made a full part of the record.

STATEMENTS OF PATRICK A. TEMPLETON, ASSOCIATE ADMINISTRATOR FOR EXTERNAL RELATIONS, NASA, AND RONALD J. PHILIPS, DIRECTOR, TECHNOLOGY UTILIZATION AND INDUSTRY AFFAIRS, OFFICE OF EXTERNAL RELATIONS, NASA

Mr. TEMPLETON. Mr. Chairman and members of the subcommittee, thank you very much for the opportunity to appear before you this afternoon. Before getting into my very brief testimony as you indicated, I would like to add a personal note, that it is a particular pleasure for me to appear before you because I enjoyed so very much my relationships with you when I was in my previous job in the Congressional Affairs Office.

Seated on my right is Mr. Ron Philips, the Director of the Technology Utilization and Industry Affairs Office, and you mentioned, Mr. Chairman, the brevity of my statement. With your permission I would not like to read my statement. What I would like to do rather is give you a very brief overview of some points that I consider to be particularly significant, reflecting the statement, and to kind of set the stage for Ron Philips' testimony to you.

Mr. VOLKMER. Proceed.

Mr. TEMPLETON. We appreciate very much the support that the subcommittee and the committee has given this program through the years; and, of course, it enjoys great popularity and support at NASA. We are very pleased to submit to you for fiscal year 1985 the TU budget of $9.5 million, which reflects a $5.5 million increase over the level of funding we requested last year. It maintains the program at the level that it currently is enjoying and helps us to build for the future.

Now, there are a couple of—I would like to make four points if I may, reflecting where we are going and how I view this program. First of all, as Ron Philips will detail, we are, in order to reach a broader segment of the business sector and the private sector, we are changing our emphasis from one of retailing the information to wholesaling it so we are taking our IAC's that we have around the country, the industry application centers, and using them as wholesaling points in reaching out through State development offices, university groupings and so forth to better disseminate to a broader range of the private sector the information that we have available in our IAC, through telemail, through new electronic communications capabilities and new search methods that Ron will get into in more detail.

Second, we are commercializing our tech briefs with the hope of increasing the circulation of that very good annual information.

Third, we are trying to upgrade the understanding among as many segments out there of the public as we can get to have the benefits of utilizing space technology here on Earth and the benefits of doing business in space. Now we are doing that through increased communications through an outreach program, and specifically we have assigned a public affairs officer to this technology utilization program, something we have never done before.

In addition to that, Mr. Chairman, we are—we have organized a number of conferences around the country to spread this message to this constituency, and the first one was yesterday in Houston, and Ron and I were both there and it attracted a great deal of attention from the business community, the media and so forth and was very well accepted. I have the agendas. I will submit them. We have another one in St. Louis coming up in April, one in Boston, and we have one in Orlando with the financial community. So those are very important programs.

Finally, Mr. Chairman, I am going to take an inspection trip to visit all the industry application centers to make sure that we are doing everything we can to get this information out to the private sector in the most effective manner that we can. We have a number of programs that are responsive to what the community has asked for in the past. We want to be sure that we are not missing anything in how we are approaching this very fine program.

With that, Mr. Chairman, I would like to turn the testimony over to Mr. Philips for his presentation and then we will answer questions.

[The prepared statement of Mr. Templeton follows:]

HOLD FOR RELEASE UNTIL
PRESENTED BY WITNESS
FEBRUARY 29, 1984

Statement of
Patrick A. Templeton
Associate Administrator
for External Relations

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the
Subcommittee on Space Science and Applications
Committee on Science and Technology
United States House of Representatives

Mr. Chairman and Members of the Subcommittee:

Thank you for the opportunity to appear before the Subcommittee to present NASA's proposed Technology Utilization (TU) Program and supporting budget request for Fiscal Year 1985. As you are well aware, this Subcommittee has consistently recognized the importance of NASA's TU Program in providing for a broad spectrum of applications such as industrial productivity, and new projects in supporting small business. Through your support NASA has been able to maintain an effective program and this past year explore and implement program changes.

In FY 1985, NASA will continue to implement program changes initiated this past year. Broadly speaking, these new initiatives will include, an emphasis on "wholesaling" rather than "retailing" of technology information. By that I mean, first using advanced techniques to disperse information through non-profit or state-sponsored industry assistance activities which would then further disseminate to their industrial clientele or other users; second, to encourage greater private sector involvement in dissemination, specifically through the commercialization of the NASA Tech Briefs journal and participation in technology applications projects; and third, to implement a more focused approach to transferring technology to high technology firms in high growth areas, such as materials, electronics and the like.

For FY 1985, the NASA budget request for Technology Utilization is $9.5 million. This represents a $5.5 million increase over last year's request yet reflects maintenance of the funding level authorized by this Subcommittee and the Congress for FY 1984. This level of funding will allow NASA to further explore new techniques and avenues for more effective and significant technology transfer.

Ron Phillips, NASA's Director of Technology Utilization and Industry Affairs will now briefly discuss the specifics of the new directions planned for FY 1985 and highlight some of the past year's accomplishments and improvements. Then, we will be happy to respond to questions.

Thank you, Mr. Chairman.

Mr. VOLKMER. You may proceed.

Mr. PHILIPS. Thank you. Mr. Chairman and members of the subcommittee, it is a pleasure to appear again before you to report on the NASA technology utilization program.

Fiscal years 1983 and 1984 to date have been a period of refocus and management strengthening in the TU program. Our basic mechanisms for technology transfer—information dissemination and technology applications—have been improved to effect increased industrial productivity, expansion of outreach and access to small business, cooperation with State economic development organizations, applications in medicine, and response to national needs.

Our approach is to "wholesale" rather than "retail." This approach is taking hold in NASA's technology dissemination program where we have initiated several efforts toward a more effective and far-reaching program. NASA's industrial applications centers are implementing modern techniques, such as remote interactive search systems, high-speed search capabilities, and electronic mail. These techniques will facilitate a higher volume of searches and provide for effective linkages between the applications centers and State economic development organizations and universities, which then can provide the service to their in-State industries and small businesses. This more dispersed system of distribution should prove especially beneficial to small businesses across the Nation, not only because of its greater affordability but also because of its accessibility. Another "wholesaling" effort is NASA's move toward a conversion of the "NASA Tech Brief" journal, our major technology announcement mechanism, to a commercial publication. "Tech Briefs" as a commercial publication should reach a broader and larger audience at significantly less cost to the Government and at no increased cost to the user.

The technology applications program, our program of transferring technologies through adaptive or applications engineering projects, is refocusing part of its efforts toward high-technology firms both large and small in high-growth areas—specifically, automation, electronics, and materials. At the same time, our efforts in bioengineering and rehabilitation will be continued. Additional steps forward in technology applications include increased outside participation in a greater number of cooperative applications projects and involvement with trade associations.

This year we are requesting a TU budget of $9.5 million which will be divided into two subprogram elements: $5.8 million for technology dissemination and $3.7 million for technology applications.

Under technology dissemination, we plan to continue improving our mechanisms for dissemination—technology evaluation, new technology announcements, industrial conferences and seminars, and computerized access to NASA's information data base. The conversion of the "NASA Tech Brief" journal to a commercial publication will be implemented in fiscal year 1985.

Under this budget, NASA will maintain its current IAC network; however, as I have said, system modernization and efficiencies will continue to be explored and implemented to further expand the market of industrial users and small businesses. At the same time greater participation and funding from a wider range of States should provide for some service expansion. We also plan to contin-

ue our technical seminars with a new emphasis on a more focused format, and to work with individual industries to match their needs to our technologies. We are also beginning work with industry associations and professional technical societies as another means to help facilitate the flow of technology.

The technology applications funding level for fiscal year 1985 will assure the continuation of applications engineering projects designed to transfer technology to the public and private sector.

I would like to report to you that just today I was told that the FDA has granted approval for a predevice exemption for a programable implantable medication system. We hope that Johns Hopkins will be able to make the first human implant some time next month or the early part of April.

In conclusion, Mr. Chairman, I believe that the budget of $9.5 million which we have requested for fiscal year 1985 will enable us to continue to maintain a very effective program. Our continuing aim is to decrease the unit costs for transferring technology, and to make NASA-developed technology available across the Nation to big business and small business alike. NASA's program has been a successful one; we intend to continue to strive toward an even better program in the future.

At this point I would be happy to take any questions the committee may have.

[The prepared statement of Mr. Philips follows:]

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PRESENTED BY WITNESS
FEBRUARY 29, 1984

Statement of
Mr. Ronald J. Philips
Director, Technology Utilization and Industry Affairs
Office of External Relations

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the
Subcommittee on Space Science and Applications
Committee on Science and Technology
United States House of Representatives

Mr. Chairman and Members of the Subcommittee:

It is my pleasure to appear before this Subcommittee to report on the activities of the NASA Technology Utilization (TU) Program.

This Subcommittee, which has demonstrated strong support for the NASA TU Program, is well aware of the contributions of NASA technology. The TU Program has provided many applications of aerospace technology to improve our industrial productivity and to stimulate new product/process development. Many segments of U.S. industry are reached by the products of NASA's technology transfer efforts. With the support of this Subcommittee, we have been able to conduct an effective TU Program.

Fiscal Years 1983 and 1984 to date have been a period of refocus and management strengthening in the TU Program. Our basic mechanisms for technology transfer -- information dissemination and technology applications -- have been improved to effect increased industrial productivity, expansion of outreach and access to small business, cooperation with state economic development organizations and applications in medicine.

With an emphasis on technology information "wholesaling" vs. "retailing," NASA's Technology Dissemination Program has initiated several efforts toward a more effective program. NASA's Industrial Applications Centers (IACs) are implementing modern techniques, such as remote interactive search systems, high-speed search capabilities and electronic mail. These techniques will facilitate a higher volume of searches and provide for effective linkages between IACs and state economic development organizations and universities, which then provide the service to their in-state industries and small businesses. This more

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dispersed system of distribution should prove especially beneficial to small businesses across the Nation, not only because of its affordability but also because of its accessibility.

NASA's move toward a conversion of the NASA Tech Brief journal, to a commercial publication is another effort directed toward more cost-effective, broader dissemination of information. A commercial publication should reach a broader and larger audience at significantly less cost to the Government and at no increased cost to the user.

The Technology Applications Program, while continuing its work in bioengineering and rehabilitation technologies, is refocussing part of its efforts toward high technology firms in high growth areas -- specifically, automation, electronics and materials. Increased outside participation in a greater number of cooperative applications projects and involvement with trade associations are additional steps forward.

We are requesting a TU budget of $9.5 million for FY 1985 which is in line with the TU budget authorized and appropriated by Congress in FY 1984. The FY 1985 request will enable the TU Program to continue implementing program improvements.

The FY 1985 TU budget is divided into two subprogram elements: $5.8 million for Technology Dissemination and $3.7 million for Technology Applications.

Under Technology Dissemination, we plan to continue improving our mechanisms for dissemination -- technology evaluation, new technology announcements, industrial conferences and seminars, and computerized access to NASA's information data base. The conversion of the NASA Tech Brief journal to a commercial publication will be implemented in FY 1985.

Under this budget, NASA will maintain its current IAC network; however, as I have said, system modernization and efficiencies will continue to be explored and implemented to further expand the market of industrial users and small businesses. Greater participation and funding from a wider range of states should provide for some service expansion. We also plan to continue our technical seminars with a new emphasis on a more focused format, and to work with individual industries to match their needs to our technologies. We are also beginning work with industry associations and professional technical societies as another means to help facilitate the flow of technology.

The Technology Applications funding level for FY 1985 will assure the continuation of transferring technology to the public and private sector through adaptive or applications engineering projects.

I would like now to review in more detail some of the improvements and accomplishments of the past and current year and our plans for FY 1985.

TECHNOLOGY DISSEMINATION

Publications

In last year's budget testimony, we reported to the Subcommittee that NASA was exploring the conversion of NASA Tech Briefs, our principal new technology announcement mechanism, to paid subscription. Research of the private publishing industry revealed that the trend in the private sector is actually in the reverse direction -- that is, from paid to free subscriptions -- relying almost exclusively on income from advertisements to offset publisher's costs. A publisher survey, conducted by NASA in late Spring, also revealed substantial interest among private publishers in a NASA-proposed concept to convert NASA Tech Briefs to a commercially viable, private sector periodical. Experienced publishers moreover estimated that the readership of NASA Tech Briefs could be doubled or even tripled if such a commercialization effort was undertaken.

Seeing this as an opportunity to work with a strong commercial partner, while broadening the exposure of our technologies to expanded audiences, NASA recently issued a competitive solicitation for the selection of a private publishing firm to take over NASA Tech Briefs as a commercial venture. Under the proposed Memorandum of Agreement to result from this solicitation, no exchange of funds will occur between NASA and the selected firm. The proposed Agreement will also allow the successful offeror to recoup costs through the sale of advertising which would be incorporated in the new publication.

This approach may establish a significant precedent, and we feel that the resultant benefits will be significant. NASA expects to save a minimum of $300,000 while achieving a significant increase in broader distribution and use of NASA-developed technology throughout the U.S. industry. Furthermore, the private sector will be given a significant opportunity to get more directly involved in NASA's technology transfer process.

Dissemination Center Network

As indicated in my introductory remarks, we have made significant headway this past year in developing new techniques for broadening the NASA dissemination center network. In CY 1983, the network saw a 19% increase in overall income. Our primary objective is to move toward "wholesaling" information by encouraging "retailing" by our IACs through university and state level programs. Our effort is aimed at expanding outreach so that NASA technology is even more accessible and affordable to small businesses across the Nation. Some of our new techniques include remote interactive search systems which are now being adopted by the three IACs located in California, Pennsylvania, and Florida.

The NASA-sponsored IAC at the University of Southern California (USC) has commitments from three states within a thirteen-state region to provide real-time information search capabilities remotely through teleconferencing techniques. Other states are considering similar commitments. This system will permit these states to effectively provide information and technology transfer services to their respective industries and small businesses by utilizing the services of the USC IAC, eliminating the costly requirement of setting up their own search and transfer capability. The USC IAC thus becomes essentially a wholesale outlet for these products and services by working through member states' institutions who in turn provide this much needed service to their own industrial firms.

A broader charter at the NASA dissemination center at the University of Florida is also now underway. Through an expanded remote interactive system, it is expected that this center can effectively provide service linkages with other universities and state institutions throughout the Southeast. This expansion of the Florida program is scheduled to involve at least three additional southeastern states by year's end with additional states to be added later, if the initial program proves effective.

A more localized experiment is also taking place at the University of Pittsburgh IAC. The Pitt IAC is now providing remote interactive searches for four university-based technology transfer centers within the State of Pennsylvania. These Pennsylvania transfer centers have been designated by the State government, under its Ben Franklin Partnership Program, to assist statewide industry in enhancing productivity and new technology development through technology transfer. Extension of this service to similar centers in other states is possible.

Over the past few years, most of the states have initiated new activities to apply science and technology in support of their business and industrial development objectives. These activities offer new opportunities for NASA to engage in cooperative federal-state action to stimulate economic growth. Several states have expressed an interest and are actively considering the investment of their own funds in this effort. NASA is coordinating with these states and others to develop the appropriate infrastructure to accommodate this access. NASA is pleased to extend its current programs and IAC network capabilities to assist these and other states in their respective industrial and economic development efforts. In FY 1985, NASA expects continued expansion and development of its network to respond to similar needs and initiatives. The importance of such cooperative efforts is to minimize initial set-up and development costs to duplicate information search capabilities and services already available through the NASA-sponsored network.

The remote interactive search systems, just described, have also been complemented by another technique to improve remote access to the NASA data base. High speed computerized search capability plus use of electronic mail to rapidly communicate search results to industrial users embodies this new effort. This experimental effort to adopt advanced computer retrieval and communications methods to information dissemination and technology transfer is being conducted by the NASA IAC at the University of Connecticut. Broader use of these more modern methods will now enable NASA dissemination centers to handle a greater volume of requests and needs articulated by an increased number of industrial firms nationwide. They also allow more effective interaction in problem solving between the IAC staff and the industrial user.

COSMIC, the NASA-sponsored software dissemination center at the University of Georgia, has continued to increase its activities nationwide in the transfer of NASA-developed computer programs to industry. Last year marked the sixth consecutive growth year for COSMIC with over $1.1 million in receipts for software sold or leased to private industry. This represents a 31% growth over the previous year.

Overall, NASA-sponsored dissemination center activity has adopted an increased small business orientation. Each center has made efforts to cultivate effective interfaces with small business firms in their regions. The IAC in Indianapolis has initiated a "Technology 2000" program designed to provide affordable technology transfer to Indiana small businesses and those small businesses considering relocation in Indiana. The program provides

technical, marketing and management assistance to small business. It can be adapted to the needs of other states within the service range of Indianapolis.

Transferring technology to small business requires a very interactive process. I believe that the expanded, more dispersed capability of our IAC network will create an environment for even more successful relationships with small businesses across the Nation.

Another activity of NASA's dissemination centers supports the objectives of the Small Business Innovative Research (SBIR) Program. Our IACs are making efforts to package information for SBIR applicants to assist them in their efforts to qualify for the program. The centers are then prepared to carry out research directed by those firms who are awarded innovative research grants. NASA, of course, is happy that it can assist small businesses; and, in FY 1985 we look forward to continuing these plus more small business interactions through our expanded network of information access.

Industry Activities

In the past year, NASA has continued its Industry Seminars Program, the objective of which is to pair nonaerospace industry with NASA's research and development centers. The program, first directed toward management executives who could commit resources to work with and apply NASA technology to product development, has been expanded to include seminar and related activities directed toward program and project engineers in a hands-on approach to selected products and processes. Two successful conferences this past year have been on advanced materials and the fibrous ceramic technology associated with the Space Shuttle's thermal protection system.

In support of and following our technical seminars, we pursued separately individual company requirements. This developing interactive relationship is essential if government is to work successfully with industry. Two years ago Mr. Gordon Millar, Vice-President of Deere and Company, testified before this Subcommittee voicing strong support of our activities. Today, Deere and Company has more than fifteen separate technical projects with NASA.

This year we intend to place increased emphasis in this area. We are beginning to work more closely with industry associations with a view toward more effectively reaching specific industries with common technical requirements and problems. For example, a relationship has been established with The National Machine Tool Builders Association which represents an industry which is under increasing technical and competitive pressure from foreign manufacturers.

TECHNOLOGY APPLICATIONS

During this past year, seven applications engineering projects were completed. Of these projects, two addressed the needs of the handicapped, two were bioengineering projects, one was advanced electronics and automation, one was engineering design and energy and one was in the area of electronics and communication. Paralleling these efforts, NASA centers completed 17 feasibility studies. These studies are the forerunners of the applications engineering projects and serve to harden the transfer concept and align the potential industrial partners. The study areas were bioengineering (5); rehabilitation (3); automation and electronics (8); and materials (1). Emphasis in the preengineering studies is shifting to a concerted effort to assist industry in technological advance in electronics, automation and new materials.

During FY 1984, several new project concepts will be implemented to assist other federal programs and major U.S. industries, e.g., Department of Transportation, National Institutes of Health (NIH), Veterans Administration (VA), the electronics industry and the materials industry. The transition between 1984 and 1985 will require more specialized studies and workshops with industry to develop the necessary matching of technology to industrial needs. Improved management flexibility and the ability to quickly support industry, university and government projects based on NASA's evolving aerospace technologies will allow us to assist U.S. industry to maintain international leadership in the world marketplace.

Applications Engineering Projects

During the past year, a major project with the State of Maryland's Department of Transportation and DALMO VICTOR was completed. The project was to demonstrate Compressed Television Transmission (CTT) for highway traffic surveillance. The technology is derived from the NASA Jet Propulsion Laboratory's data compressed technology which was developed to transmit TV images from spacecraft over limited bandwidth communications links to the Earth. Existing transmission of live TV imagery requires costly, high data rate communication links. Conversely, current slow scan TV operates over low cost phone lines, but frame rates are too slow for effective freeway traffic monitoring. The NASA CTT technology offers a possible solution to improving highway surveillance, safety, and accident rescue.

NASA's Marshall Space Flight Center (MSFC) is assisting the Federal Emergency Management Agency (FEMA) in demonstrating a Firefighter's Training Simulator concept. Using NASA developed simulation technology, a portable simulator system is being developed by industry, FEMA and NASA, to allow instruction and training to firefighters by simulating realistic emergency firefighting situations or environments.

In the past year, arrangements were made through the Goddard Space Flight Center (GSFC) to enter into a joint agreement with the VA to develop a multi-channeled tissue stimulator. The stimulator will be developed as a joint government, university and industry project. Based upon the development of an earlier NASA "Spinoff" to Pacesetter, Inc., the tissue stimulator will be designed to help para and quadraplegics achieve various degrees of mobility. Project initiation should be in late FY 1984, and will require a substantial investment from the VA, NASA and industry in 1985.

In another effort, NASA's Lewis Research Center (LeRC), Applied Medical Technology, Inc. (AMT) and American Hospital Supply Corporation (AHSC) are cooperating in the design, fabrication, ion beam texturing and testing of a new medical device known as the Percutaneous Connector. This device will allow direct and continuous access through the skin into blood vessels. Its application could benefit hundreds of thousands of people each year who undergo hemodyalysis, chemotherapy, and other major treatments that require prolonged infusion into the body's vascular system.

FY 1984 will see final negotiations to transfer the NASA LeRC REDOX Energy Storage System technology to SOHIO. Although the technology has been available to other U.S. firms, SOHIO was the first to step forward with a firm commercialization commitment. SOHIO is interested in commercializing the technology as a solution to an existing need for electrical energy storage systems.

Another project, the Programmable Implantable Medication System (PIMS), is an excellent example of how NASA, through effective technology application, can work with other Government agencies, universities and industry to solve important technical problems. The potential of this important medical system for the future was realized as a result of the cooperation of two NASA Centers (GSFC and MSFC), Johns Hopkins University, Baker Foundation, Johns

Hopkins Hospital, National Institutes of Arthritis, Diabetes and Kidney Diseases, National Institute of Child Health and Human Development, Pacesetter Systems, Inc., Parker-Hannifin Corporation, Teledyne, Inc., and Wilson Great Batch. This system is now awaiting approval by the Food and Drug Administration for the first human implant. One of the animal implants has now been in operational use for one and a half years. The results so far have been good.

SUMMARY

In conclusion, Mr. Chairman, as I noted earlier, the Technology Utilization budget request for FY 1985 is $9.5 million. It is in line with the budget levels of FY 1983 and FY 1984 and I believe will enable us to continue to maintain a very effective program. Our continuing aim is to decrease the unit costs for transferring technology, and to make NASA-developed technology available across the Nation to big business and small business alike. NASA's Program has been a successful one; we intend to continue to strive toward an even better program in the future.

Mr. VOLKMER. Thank you, Mr. Philips.

The gentleman from Florida.

Mr. NELSON. Mr. Philips, how much did NASA request last year for this program?

Mr. PHILIPS. Mr. Nelson, we requested $4 million for fiscal year 1984.

Mr. NELSON. $4 million. And the Congress gave them 9.5 million?

Mr. PHILIPS. That is correct. The Congress authorized and appropriated $9 million for fiscal year 1984.

Mr. NELSON. $9 million?

Mr. PHILIPS. That is right.

Mr. NELSON. And it was $4 million. Were you here? You know Pat was. He wasn't in his position that he now is. By the way, what does external affairs mean, Pat?

Mr. TEMPLETON. External relations at NASA is made up of all of our relations with the outside world save the Congress.

Mr. NELSON. I think it is one of the most important jobs at NASA.

Mr. TEMPLETON. I agree, with the exception of Mr. Beggs' job.

Mr. NELSON. I agree and I think he has one of the best jobs in Government. Do you publish that book "Spinoffs"?

Mr. TEMPLETON. Yes, we do.

Mr. NELSON. You ought to make that mandatory reading for every NASA employee.

Mr. TEMPLETON. There is a lot that we can do and Ron's office has been doing a great deal to get this information out and I am going to lend all the support I can to do those kinds of things. We have been doing a good job, but I think we can do more.

Mr. NELSON. Mr. Philips, were you here a year ago when we had this hearing?

Mr. PHILIPS. Yes, sir. Bob Allnutt and I testified last year. He has left the Agency and joined the Center for Energy Awareness.

Mr. NELSON. You remember my discussion with you last year about how I thought you were being short-sheeted by OMB when you come forth with 4, remember that?

Mr. PHILIPS. Yes, sir.

Mr. NELSON. And instead it went to 9 so in essence you are asking for a half-a-million-dollar increase from 9 to 9.5?

Mr. PHILIPS. That is correct.

Mr. NELSON. And things are looking better. What I want to ask you is of this 9½ that you are requesting, about 58 percent of it is going to the headquarters, and of what you requested for fiscal years 1984 and 1985, about the same percentage, even though you requested a lot less. Why so much at the headquarters if this is a dissemination program?

Mr. PHILIPS. Mr. Nelson, we implement the dissemination program out of the headquarters. That means that we contract our industrial application centers, the bulk of our publications activities, out of the headquarters. In that sense, we act as a program office in a field center. The technology applications program is primarily carried out at the field center level so that when you look at the numbers, what you are looking at is a situation of where the program office in the headquarters is implementing or executing the $5.5 million portion of the budget for dissemination activities.

Mr. NELSON. Well, now you talked about applications and dissemination. Now, of the $5.8 million you are asking for technology dissemination, is that same percentage, about 58 percent, is that used at the headquarters?

Mr. PHILIPS. Yes, essentially that is correct.

Mr. NELSON. So it runs through both of them, the applications and the dissemination?

Mr. PHILIPS. No, sir, that is not correct. Let me restate that. Of the technology applications portion of the technology utilization budget, I would say that less than 10 percent of the applications portion of the budget is executed out of the headquarters. That money is transferred through the RTOP system to the field centers. They work with the academic and the medical research industrial community to develop applications engineering programs directed toward needs in the medical and industrial communities and the field centers actually execute those projects.

Mr. NELSON. In this case field centers, what do you define as field centers?

Mr. PHILIPS. Goddard, Marshall, Kennedy—NASA centers.

Mr. NELSON. Are there any gremlins there that I do not see and that you can convince me aren't there, than 58 percent of this stuff for—let's see—dissemination, even a higher percent on dissemination. It would be upwards of 68 percent on dissemination is being spent at headquarters. Convince me that there are no gremlins.

Mr. PHILIPS. Well, I am not sure precisely what you mean by a gremlin.

Mr. NELSON. I mean if you are disseminating technology information, convince me that we are not putting it into a bunch of administrative overhead and it is not getting disseminated.

Mr. PHILIPS. Let me give an example. We contract with the Florida State Technology Application Center directly out of the Headquarters program office. The Florida STAC disseminates the tech-

nology. They staff the STAC. They search the data base. They solicit the customer or the clients and they actually implement their portion of the program right at the University of Florida in Gainesville in conjunction with the university community in the State of Florida. So, the headquarters program office contracts directly with the Florida STAC. And, that is very typical of what we do with the rest of the program, the other IAC's and State Technology Application Centers. In addition to that, in the Headquarters program office, we execute the publications program as well, again under contract, and that produces the "Tech Brief Journal" and that produces the Spinoff magazine with which you are familiar. So in a sense you could conceivably look at our program office simply the way you would look at a space flight with the exception that we do execute a large portion of the program out of that program office.

Mr. NELSON. What I would like you to do is, rather than taking the time here, dissemination of technology says exactly what it says in its title, and I just want you to convince our staff that indeed it looks like what this percentage is now, about 70 percent of the $5.8 million that you are requesting for technology dissemination is spent in the headquarters, and I just want before we start marking up a bill allocating this money the staff to be convinced that in fact it is not overly, unduly burdened with administrative junk at the headquarters level but in fact it is getting disseminated.

Mr. PHILIPS. All right.

[The information follows:]

The $5.8 million requested to carry out NASA's Technology Dissemination Program is divided among three areas: Publications, Dissemination Centers, Program Evaluation and Support. These are R&D funds and are spent only for R&D activities. Though it appears that a large portion of the budget is spent at Headquarters, it is merely administered from Headquarters in the form of contracts to support these dissemination activities. Funds for salaries and administrative support of Headquarters' staff, including travel expenses, are taken from the Resources and Program Management Budget. The following figures from the FY 1984 operating plan roughly outline how funds are allocated.

	Thousands
Technology dissemination	$5.5
Publications: contracts with Stanford Research Institute (new technology evaluation) and Logical Technical Services (publication preparation) represent the 75% of this funding; other activities include Special Publications and Projects, largely contracted efforts	1.1
Dissemination Centers: NASA's portion of the support for the nationwide Industrial Applications Center Network contracted from Headquarters	2.7
Program Evaluation and Support: contracted efforts for evaluating the effectiveness of the Technology Utilization Program, for conducting the Industry Conference Program, and for Technology Utilization-related costs at the Scientific and Technical Information Facility (NASA's technical information data base)	1.7

Mr. NELSON. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you.

Also as part of the hearing we have a good friend and colleague of ours, a former member of the full committee and of this subcommittee, Congressman Wes Watkins of Oklahoma.

Wes, do you have any questions? I think we all know of your interest in this program and how you have helped to keep it going

and helped develop it, so if you have any, we welcome comments or questions.

Mr. WATKINS. Thank you, Mr. Chairman. I appreciate the invitation to come back down and hear one of my favorite subjects. I truly enjoyed this committee when I served on it, the full committee as well as the subcommittee, and I guess having to leave and go on the Appropriations Committee, I guess one of the things I try to enjoy is making sure I protect certain things of NASA and certain things of technology utilization, because I do have as the chairman said a very keen interest. I know Mr. Volkmer and Mr. Nelson both know of my interest in this program and many people at NASA know. I think it is one of the best things that we have going and I am one that believes we should expand a very practical application of technology transfer from not only NASA, but all of the Federal laboratories of the Federal Government. I say that from the standpoint of an agriculture background, and without question the leader worldwide in technology transfer has been the American ingenuity in agriculture, where we have taken 10 percent of the research money going to agriculture, it goes to agricultural experimental stations and our various research centers in agriculture, but 10 percent of it is basically designated to use to not just disseminate, but to take the technology developed in agriculture, take it to the extension agents, the extension arm, and also vocational agriculture teachers, which happens to be my background, and we teach our young people, and many people who have an interest, on how they can be more productive by taking new technologies, whether we use a new hybrid seed that was developed on a research farm and take the fertilizer and use it someplace else and say if we use this we can produce more, and that is what we have done in America.

We are producing the food and fiber for this country and for over one-fourth of the world. Agriculture has led the way and we need to be and should be doing more. I say that because that is where I developed an interest. I started observing and evaluating what was happening in NASA and I was glad to find that NASA technology utilization mandate. Unfortunately we spend about $45 billion or more on research on a Federal level, but we do not mandate or we have not mandated that they get the technology out to the people in America.

Under the Stevenson-Wyler Act, chapter 11 is a bill that I authorized. I started out trying to get 10 percent of the research money for technology transfer in the laboratories to go, could not get it passed, could not get 5 percent, maybe I am editorializing to my fellow Members and lobbying, I finally got one-half of 1 percent set aside under Stevenson-Wyler of research money to be utilized for technology transfer so each major laboratory has a technology transfer person out there today.

I know, Bill, when I went down to Kennedy I asked to see the technology transfer person and I think everyone at Kennedy looked at each other and realized that is the first time that person had been asked for by a Member. Because we have a lot to offer in America to increase the productivity in America, we have a lot to offer to try to expand the gross national product and we know we have got to do it. If not, if we remain static or constant in the gross

national product, we either have to tax it a lot more or we have to cut back the quality of life in America. That is the only two choices we have, and we have a good deal more chance of expanding our gross national product if we bring technology on board and not just disseminate it—there was a difference in dissemination and technology transfer and I am proud of you at NASA, the technology utilization program has broken down into dissemination and also technology applications, because in many of our areas, especially an area like I come from, a rural, low-income area, we are trying to give birth to industry to get the smokestacks to come there or major industry, and we are utilizing technology not only from NASA but every source we can.

And so I am pleased, when I was talking to my staff to try to review what was happening, that not like in 1983 when you came with a $4 million budget for technology utilization or in fiscal year 1984 when you came with a $4 million request, and this committee in the wisdom of the chairman and the members gave $9 million for technology utilization, I am pleased this time that you have come forth with a request for $9.5 million. I think that is a giant step forward for a realization of what might be done. I want to commend you so much for that. I think I noted how that 9.5 would be divided down to $5.8 million for technology dissemination; is that correct?

Mr. PHILIPS. Yes, sir.

Mr. WATKINS. And $3.7 million for technology applications that is under your request. Under your fiscal year 1984, how did you have that broken down? Could you tell me what you——

Mr. PHILIPS. Mr. Watkins, on a percentage basis it is roughly the same.

Mr. WATKINS. Roughly the same percentage——

Mr. PHILIPS. The same percentage as what we are requesting in fiscal year 1985, about 5.6 and 3.4, very close to being the same proportion.

Mr. WATKINS. I have an interest in both, but I see the application being a little more on the practical side of trying to get some things. I think one of the big things, Mr. Chairman, with the privilege of the committee, I would like to introduce a person who helped ride part of this technology into outer space, who by coincidence just had an office appointment with me about this hour and I had to come here, but Pete Conrad. He is one of the astronauts that rode some of this technology to outer space.

Mr. NELSON. His picture is right over there, and that doesn't look like the same person.

Mr. WATKINS. Pete looks younger today with some of that technology developed in outer space, but he is back on the ground with us today, on earth, contributing in many more ways.

But I think the practical application—as I tell them, we have a tremendous story to tell with the space shuttle and other things, but a lot of people on Main Street America ask many of us about the budgets and the deficits and whether they see a promise for space programs and all. Many of them get very practical, saying, "How is this going to benefit us?"

Mr. TEMPLETON. Mr. Watkins, I would like to comment.

Mr. Nelson has asked what external relations at NASA was, and it includes public affairs. One of the things we are going to do now is step up our efforts tremendously in this outreach area to use every mechanism that we have to get that message out, because it is a tremendous message. You are right; and, we are going to increase those efforts.

Mr. NELSON. We have got some people excited, and we have to make that effort. We have done it in agriculture.

I think NASA has broken not only the technology and going into outer space, but we can break the technology on increasing productivity for business and industry if we will pursue it with the same type of interest as we have in agriculture.

But we haven't done that in the American ingenuity of our Federal research. Let me ask a question on this.

How are you—you are basically, I know, implementing the Stevenson Wyler chapter 11, but your relationship with the Federal Laboratory Consortium and the Center for Utilization of Technology, do you have a practical working relationship with those?

Mr. PHILIPS. We participate in the discussions with the Federal Laboratory Consortium through our Technology Utilization offices in the field centers, and we have a continuing discussion with the Department of Commerce in a number of different areas including C of F.

But, probably the most practical element of our relationship with the Department of Commerce in the context of the technology transfer is with the SBA and participation in the SBDC program and in the SBIR program, where we can have usefully and very practically make information available to small business or enterprises who are complying, responding to a solicitation, not just a NASA solicitation but any one of the several agencies participating in the SBIR program.

So, we have a continuing relationship. We produce very useful information in the Agency which is readily accessible by individuals or small businesses for the purposes of doing a sound technology program.

Mr. NELSON. You know in all respect to that, and I will say probably in the chairman's district and my district, I know in my district, if we didn't have the rural application team making a genuine external outreach to educate the business and industrial people in that outreach of what has to be done and would be available, my people would not know you existed, and I will bet that the same position that the chairman of this subcommittee's district would be in there is not a direct thrust, because dissemination of information doesn't do the job.

We have got to make sure we are out there initiating, implementing, leading, on the cutting edge with trying to get this technology utilization out there, the same way we have in trying to get the program in outer space as we are doing today with the shuttle.

The only thing I am trying to say, with the subcommittee's and with the subcommittee's dedication and leadership, we need to get on the cutting edge and implement out across America these programs more, and I would like to think that we might do so. But I worry; I am like many people.

Spinoff is one of the best publications, I think, that comes down the pike, but many times it is not—it is in certain areas, but it doesn't reach the masses of people across the country.

I am concerned again still about the attitude about, we got to charge on getting this information to the people. We charge the taxpayers for the space program; that is one charge; and I believe that it would pay tremendous dividends if we could even just get this information out there to the people in order for them to increase their productivity, their tax producing potential. This would put tax dollars back into this coffer and not have to pay for it again.

They are paying for it not just twice, but three times, because when they make money, we pay taxes; if they have to pay to get it, they pay taxes, and they have to pay taxes to the space program.

So I think we are doing a disservice in some respects by charging the people to get technology information to them that they have already paid for; they have to pay for it again and taxes on the benefits from it.

I have been on record against this because you basically do not have to pay for the agriculture technology. In fact we pay agents to get it out there. We pay them to get it out to the businesses and industries in agriculture. We want them to use it. We want to produce, but we haven't got that attitude in other areas.

We say, "We are going to charge you if you are going to use it," and I think that we are doing a disservice, and I hope that we don't continue.

I know I probably have a time limitation here. This committee has been great to me. But I want to express—I hope that you will continue to work very closely with the Federal Laboratory Consortium in carrying out, I know, above and beyond the call of duty because you have a mandate and the C of T activity, and trying to improve your applications teams out there, which one is working in my area, and I see firsthand how they are making every effort to implement it in some of these communities, and we have some people utilizing it.

We have got the percentage on doing it now, and I want to thank you, Mr. Chairman, for your commitment, personal commitment, to helping me carry out this program and your keen interest.

I think that some of the things that are going on in this room and this subcommittee with technology utilization, in all respects—if we were here talking about the astronaut or the shuttle program, the room would probably be filled, but lots of times the result here, where we really need to build a tax base for the GNP—we find people go the other way.

It is kind of like a pay increase. The galleries are full of the press when we have a congressional pay increase being debated on the floor, but when we have a record-breaking budget deficit on the floor, there is not anyone in the gallery. Watch it. It is kind of like here. Technology utilization, I think, is very important. I want to express my deep appreciation for the job you do.

I don't have a lot of questions because I am so familiar with the program. I warn not to dilute what can be done out there. You have some advocates here that believe in you, and I probably am

only second behind the chairman in an interest in making sure this program is out there and serving the American people.

Mr. Chairman, I thank you for letting me come down, and the staff for letting me have this opportunity.

Mr. VOLKMER. That is quite all right, Congressman Watkins.

I have some questions just so I have a better understanding of the use of the funds too and how some of this is applied.

Of the 5.8 for technology dissemination, what part of that will go to the centers? If you can't give us this right now, you can give it for the record.

Mr. PHILIPS. Mr. Chairman, under the $9.5 million budget level, approximately $3 million of the $5.8 million would go to support the industrial applications centers and the State technology application centers across the country, but $1.2 million of the balance will be spent in support of our publications programs where we are collecting new technology information, we are repackaging it, and putting it into a product form that is easily disseminated to a wide variety of people across the country.

Mr. VOLKMER. Is that in the technical brief?

Mr. PHILIPS. The technical brief program would be a part of that publication program; is that right?

Mr. VOLKMER. Do you have other publications besides that?

Mr. PHILIPS. We have Spinoff, and we also prepare The Technical Brief Journal. It is an announcement mechanism. Approximately 20 percent of the technical briefs themselves would be adequate for a scientist or engineer to use in applying the technology. So, in support of the balance of the technical briefs, we build something called a technical support package, so that someone who sees an item of technology in the Technical Brief Journal requests additional information, we have the complete information available in a package form which we can easily mail to him on request, and that is a major element of our publications program.

Mr. VOLKMER. So you build up those packages for each announcement basically that is in the technical brief?

Mr. PHILIPS. That is correct, sir.

Mr. VOLKMER. That is all part of it also?

Mr. PHILIPS. Yes, that is part of the publications portion of the dissemination program.

Mr. VOLKMER. Out of this total, how much of the total would go for what I would call percentage at headquarters?

Mr. PHILIPS. This is an R&D budget, sir; none of the money in the TU program or requested in fiscal year 1985 goes to pay salaries of NASA people.

Mr. VOLKMER. Not even yourself?

Mr. PHILIPS. No, sir.

Mr. TEMPLETON. That is separate.

Mr. VOLKMER. That goes out in the management part?

Mr. PHILIPS. It is out of the R&PM budget.

Mr. VOLKMER. On the Technical Brief Journal, I read with interest the promise to make it into a paying proposition, let's say, or at least turn it over to a private publisher and let him sell advertising and put it out in that format. Would that be a freebie?

Mr. PHILIPS. Yes. What we have asked the publishing industry to do is propose to commercialize the Technical Brief Journal along

the following lines. They would be responsible for printing, publishing, marketing, and making available the document sustained by advertising, and it would be provided at no cost, at no subscription fee, to a qualified mailing list.

The basic reason for going this direction is that we have a ceiling on the number of free distribution that we can provide, and that ceiling has been at 75,000 people.

We believe that if we get a good aggressive publishing firm to undertake this enterprise, that we may be able to increase the readership of the document two to three times. So—because of their capability to more aggressively market the document, that would please us very much.

Mr. VOLKMER. And without any additional cost. In fact, I see there is a possible savings to the program.

Mr. PHILIPS. In this—if we succeed in getting a qualified publishing house, we would no longer be responsible for the actual printing and maintenance of the subscriber list and associated postage.

Mr. TEMPLETON. Which is part of that headquarters figure that Mr. Nelson was asking about.

Mr. VOLKMER. Right.

Now, in the technology applications I read with interest some of the applications that are ongoing.

Basically, as I analyze this—correct me if I am wrong—this is basically taking existing technology and still through our centers along with private sector institutions, universities—taking it from there to where it has an application in either a commercial or institutionalized sector; is that correct?

Mr. PHILIPS. That is correct.

Mr. VOLKMER. In other words, upgrading it to that point?

Mr. PHILIPS. That is correct, carrying it through to a practical application that can be used by people.

Mr. VOLKMER. How is the determination made, and who makes it as to which one of these technologys should be upgraded or brought to this point?

Do you have programs that come in from the various sectors to do this, or do you look at something and say, "Hey, we can do this with this if we can get so and so to do it"? How is it done, and who does it?

Mr. PHILIPS. We operate the technology applications program much like we would operate any other research and development program through our field centers. We put out a call annually or RTOP's. Our RTOPs are different than the traditional NASA RTOP's in that we ask the field center personnel in conjunction with our technology applications team to first identify emerging technologies at that particular center. Second, we ask that applications team which is working with industry, medical instutitions, other Federal agencies, and their continually serving needs, requirements, opportunities for new products, for problem solutions, and so on. We then, in conjunction with—the field center personnel in conjunction with the application, team then make recommendations back to the headquarters for funding of a specific RTOP.

The first amount of funding is very small. It is basically a phase zero feasibility analysis to assure ourselves that indeed the technology is available, it is ready to be transferred. If we in the system

agree with that, we then proceed to a phase A study where we do a thorough requirements analysis, conceivably at that point even some preliminary design work, to make sure that everything still is moving forward. Also at that time we make a determination that the industry or other Federal or State agency funding is available.

The proportion of funding on an individual project that we undertake starts out with a larger percentage being NASA in phase zero and phase A, but as we proceed through prototyping and product development and clinical and field testifying, the burden of funding shifts to the companies involved or to the other Federal agency and the companies involved, and we slowly phase our funding down. If you think of it in terms of phases C and D, we would put no NASA technology utilization money into the phases of C and D. That would be industry money or derived from other Federal agencies who are participating in our program.

So, it is a very thorough approach analyzed at three different levels sectionally, to make sure that all of the elements are there when we start to begin to apply funding to move the technology forward into the product or prototype and product stages.

Mr. VOLKMER. But what I am hearing—I don't know if it should be expanded or can be expanded, but the initial idea or design or concept comes from the field centers, Kennedy or Johnson or Marshall or someplace, Goddard?

Mr. PHILIPS. The initial idea or requirement or need can come from a variety of different sources. It can come from our application team, which is continually working with industry, medical institutions, and others. It can come out of requests made to us by outside organizations.

For example, we are developing—we have a relationship——

Mr. VOLKMER. In other words, can any university or any private enterprise that has an idea come up and make a suggestion to you?

Mr. PHILIPS. Yes, they can make a suggestion to us. We would look at the significance of it across the industry as a whole, but the final determination would be whether or not NASA has any technology which may help or may solve that particular problem. We are looking for problems of considerable significance.

Mr. VOLKMER. I agree with you, but I am trying to make sure that the NASA centers, along with your application team, aren't the only ones that are coming in here and saying that we think that this new technology of NASA can have an application in the commercial world.

Mr. PHILIPS. No; that is really just a part of it. For example, we have underway now discussions with the American machine tool industry. We have sat down with the R&D committee of the Machine Tool Builders Association. They have come forward with what they feel are the seven or eight most critical technological problems facing the American machine tool industry.

Mr. VOLKMER. Can I interrupt?

Mr. PHILIPS. Yes.

Mr. VOLKMER. Who initiated that?

Mr. PHILIPS. That was basically initiated by the machine tool industry itself.

Mr. TEMPLETON. That is one of the reasons why the outreach program is so important. So the kind of thing you are talking about——

Mr. PHILIPS. I just met with the R&D committee of the Industrial Institute on the same basis. They initiated the meeting with me, and they have a number of what they consider to be crucial technological needs in several of their industries. They are coming to NASA to see if they can develop a relationship to explore whether there were emerging technologies in NASA which may solve one or more of those problems.

Mr. VOLKMER. Is there or not in the technology utilization a thrust in such things as material, various types and uses?

Mr. PHILIPS. Yes, sir. We feel that one of the major technical strengths in NASA for industrial purposes is in our materials technology base. As a consequence, last year we held two materials conferences where we believe we had a good percentage of some of the best materials people in industry in attendance. We held one at Langley on general materials, had our best people discussing their technologies, primarily focused on composites there. We held a second materials conference at the Johnson Center where we focused primarily on fiber ceramics. We had an excellent attendance and got an excellent response to those conferences.

So we pick areas in our outreach program where we feel we have major strengths, and materials happens to be one of those.

Mr. VOLKMER. At whom are these activities targeted on these materials, on the new materials and the processing?

Mr. PHILIPS. Really our basic industries, although we really get a mix of people. When we campaigned those two particular meetings, we probably sent 25,000 small fliers out to people that were qualified off of several industry mailing lists and other places where we were satisfied that we were reaching the best materials people in those companies or institutions; in some cases, academic institutions around the country.

It is an art form, Mr. Chairman. I wouldn't argue it is a science. But we do believe that we have a pretty good system for getting that type of information into the hands of the right people. We can't guarantee that, of course.

Mr. VOLKMER. This would include non-aerospace companies?

Mr. PHILIPS. This entire effort is focused on the non-aerospace portion of the business community in this country.

Mr. VOLKMER. Do you obtain any revenues from your technology utilization activities?

Mr. PHILIPS. Yes, sir, Mr. Chairman. The Industrial Applications Centers charge a nominal fee for providing information services to industry. Those fees partially offset the cost of operations of those centers.

In 1983, those centers, plus the Computer Software Management Information Center at the University of Georgia, which disseminates software, generated I believe something in the neighborhood of about $6 million to offset operating costs in those centers.

Mr. VOLKMER. Are you telling me that $6 million went back into the center?

Mr. PHILIPS. That is correct, sir.

Mr. VOLKMER. Is the money, in other words, paid into—we have how many? Three centers?

Mr. PHILIPS. No, sir. We have 10 across the country.

Mr. VOLKMER. Ten. All right.

To the 10 centers, do they keep that within their own or does that come into headquarters and then you allocate it back out?

Mr. PHILIPS. No, sir. That money is retained by the host institutions. The host institutions spend that money to offset salary and overhead costs, equipment, costs associated with the provision of those services. It allows for a larger, more aggressive activity——

Mr. VOLKMER. In other words, operating costs?

Mr. PHILIPS. Operating costs.

Mr. VOLKMER. You also give them additional funds for operating funds out of the general revenue that we have?

Mr. PHILIPS. Our funds go for about—well, for two major types of activities. We capitalize these centers, if you will, in the hardware and systems areas to allow them to be modern and efficient. We do also offset some of the operating costs that they cannot offset out of operating revenues, out of sales.

Mr. VOLKMER. Do you have something you can furnish to the committee that would show a breakdown of that by center, et cetera?

Mr. TEMPLETON. Yes.

Mr. VOLKMER. Reimbursable amounts coming in——

Mr. TEMPLETON. We have all that.

Mr. VOLKMER. I would appreciate that for the record.

[The information follows:]

The following chart indicates NASA support of the Industrial Applications Centers (IACs) over the past five calendar years. It includes the percentage of total funding which is provided by NASA, the cooperating institutions and the income of the centers. You will note that the NASA share of total IAC funding has shown a 10 percent decrease over this time period while the income percent has increased by 10 percent.

NASA INFORMATION DISSEMINATION CENTERS
OPERATING BUDGETS (1979-83)
($ in thousands)

CENTER**	CY1979	Percent	CY1980	Percent	CY1981	Percent	CY1982	Percent	CY1983	Percent
ARAC	701	100.0	727	100.0	739	100.0	720	100.0	727	100.0
NASA	305	43.5	301	41.4	276	37.3	225	31.2	199	27.4
ARAC SHARE	34	4.9	31	4.3	33	4.5	35	4.9	38	5.2
INCOME	362	51.6	395	54.3	430	58.2	460	63.9	490	67.4
KASC	656	100.0	528	100.0	582	100.0	617	100.0	671	100.0
NASA	250	38.1	334	63.3	269	46.2	249	40.3	228	34.0
KASC SHARE	195	29.7	85	16.1	116	19.9	67	10.9	169	25.2
INCOME	211	32.2	109	20.6	197	33.9	301	48.8	274	40.8
NCSTRC	535	100.0	533	100.0	454	100.0	598*	100.0	418	100.0
NASA	225	42.1	225	42.2	200	44.1	214	35.8	176	42.1
NCSTRC SHARE	200	37.4	212	39.8	180	39.6	272	45.5	167	40.0
INCOME	110	20.5	96	18.0	74	16.3	112	18.7	75	17.9
NERAC	2187	100.0	2186	100.0	3443	100.0	3148	100.0	3894	100.0
NASA	355	16.2	408	18.7	300	8.7	250	8.0	488	12.5
NERAC SHARE	282	12.9	278	12.7	436	12.7	540	17.1	559	14.4
INCOME	1550	70.9	1500	68.6	2707	78.6	2358	74.9	2847	73.1
TAC	595	100.0	686	100.0	640	100.0	567	100.0	641	100.0
NASA	250	42.0	306	44.6	292	45.6	242	42.7	258	40.2
TAC SHARE	25	4.2	33	4.8	34	5.3	27	4.8	50	7.8
INCOME	320	53.8	347	50.6	314	49.1	298*	52.5	333	52.0
WESRAC	526	100.0	539	100.0	554	100.0	406	100.0	508	100.0
NASA	250	47.5	253	46.9	256	46.2	250	61.6	266	52.4
WESRAC SHARE	73	13.9	46	8.5	44	7.9	37	9.1	34	6.7
INCOME	203	38.6	240	44.6	254	45.9	119	29.3	208	40.9

CENTER **	CY1979	Percent	CY1980	Percent	CY1981	Percent	CY1982	Percent	CY1983	Percent
KIAC	275	100.0	321	100.0	286	100.0	259	100.0	215	100.0
NASA	175	63.6	194	60.4	161	56.3	150	57.9	135	62.8
KIAC SHARE	56	20.4	47	14.6	92	32.2	68	26.3	72	33.5
INCOME	44	16.0	80	25.0	33	11.5	41	15.8	8	3.7
COSMIC	912	100.0	766	100.0	992	100.0	1000	100.0	1361	100.0
NASA	383	42.0	227	29.6	250	25.2	156	15.6	250	18.4
COSMIC SHARE	43	4.7	0	0.0	0	0.0	0	0.0	0	0.0
INCOME	48.6	53.3	539	70.4	742	74.8	844	84.4	1111	81.6
FLSTAC	239	100.0	457	100.0	523	100.0	590	100.0	665	100.0
NASA	114	47.7	221	48.4	200	38.2	213	36.1	210	31.6
FLSTAC SHARE	111	46.4	207	45.3	271	51.8	331	56.1	336	50.5
INCOME	14	5.9	29	6.3	52	10.0	58*	9.8	119	17.9
KYSTAP	307	100.0	303	100.0	353	100.0	319	100.0	316	100.0
NASA	143	46.6	131	43.2	168	47.6	150	47.0	146	46.2
KYSTAP SHARE	163	53.1	156	51.5	176	49.9	167	52.4	168	53.2
INCOME	1	0.3	16	5.3	9	2.5	2	0.6	2	0.6
TOTAL	6933	100.0	7046	100.0	8566	100.0	8236	100.0	9416	100.0
NASA	2450	35.4	2600	36.9	2372	27.7	2099	25.5	2356	25.0
INSTITUTION SHARE	1182	17.0	1095	15.5	1382	16.1	1544	18.7	1593	16.9
INCOME	3301	47.6	3351	47.6	4812	56.2	4593	55.8	5467	58.1

* - Estimate
** - Legend Attached

Legend

ARAC - Aerospace Research Applications Center, Indianapolis, IN

KASC - NASA Industrial Applications Center, Pittsburgh, PA

NCSTRC - North Carolina Science and Technology Research Center, Research Triangle Park, NC

NERAC - New England Research Applications Center, Storrs, CT

TAC - Technology Applications Center, Albuquerque, NM

WESRAC - NASA Industrial Applications Center, Los Angeles, CA

KIAC - Kerr Industrial Applications Center, Durant, OK

COSMIC - Computer Software Management and Information Center, Athens, GA

FLSTAC - NASA/Florida State Technology Applications Center, Gainesville, FL

KYSTAP - NASA/UK Technology Applications Program, Lexington, KY

Mr. VOLKMER. Would you say that you are targeting high growth or high technology type of companies?

Mr. PHILIPS. We are shifting our focus slightly toward those industries and companies known as industries that we believe can take best advantage of some of our more advanced technologies, materials, electronics, and automation. So we are—we hope we are not doing it to the detriment of any other elements of the program. But we are attempting to focus a bit more in those areas because we believe that our technologies in some areas make a very good match with high growth, high technology industries—communications, materials industries, electronics industries, and so on.

Mr. VOLKMER. Well, let's put it this way: Are they the ones that are usually probably trying to keep up and keep informed with what you are doing anyway, and what is coming about with research and development in any type of technology?

Mr. PHILIPS. In many cases, the sunrise industries are more aggressive in seeking out other technologies. However, it is also true that they are running so fast competing with our off-shore friends that they do not always pay attention to technology being developed in Federal laboratories, particularly, of course, the technologies in the laboratories we are talking about.

Mr. VOLKMER. But you are not going to abandon the others that are not into high technology, basically the older line type of industry, and that type?

Mr. PHILIPS. No, sir, in fact, I mentioned the American Machine Tool Builders. They clearly, at this point, would not be considered to be a high technology industry.

On the other hand, they believe, and we believe with them, that there are a few things, a few technologies, if they had them available to them and could implement them, that may just change the balance a bit, with regard to their off-shore competition.

Mr. VOLKMER. So they could compete better?

Mr. PHILIPS. Yes, sir.

Mr. TEMPLETON. There are lots of opportunities with the smokestack industries.

Mr. VOLKMER. You mentioned you got in a little bit on your involvement in the SBIR program, and I believe when Congressman Watkins was here—how much will NASA spend on SBIR in 1985; or do you know?

Mr. PHILIPS. Mr. Chairman, that program is not under my jurisdiction.

Mr. TEMPLETON. I don't recall the figure offhand, Mr. Chairman.

Mr. PHILIPS. Mr. Aller says he estimates approximately $13 million.

Mr. VOLKMER. Who is in charge of that, so we can direct some written questions to him?

Mr. PHILIPS. Mr. Carl Schwenk,

[The information follows:]

In the SBIR program, NASA will spend approximately $13 million in FY 1984 and $24 million in FY 1985.

Mr. VOLKMER. Well, thank you very much. I have no further questions.

Does the staff have anything else?

We appreciate your being here, Mr. Templeton.

Mr. TEMPLETON. Thank you, Mr. Chairman.

Mr. VOLKMER. Mr. Philips, you have been very helpful and we look forward to continuing with a program for better technology for the whole country. As Wes Watkins says, we are on the road to competition. We will be able to compete.

Thank you very much.

[Whereupon, at 3:20 p.m., the subcommittee adjourned, subject to the call of the Chair.]

1985 NASA AUTHORIZATION

THURSDAY, MARCH 1, 1984

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON TRANSPORTATION, AVIATION, AND MATERIALS, AND THE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS.

Washington, D.C.

The subcommittees met, pursuant to notice, at 10:05 a.m., in room 2325, Rayburn House Office Building, Hon. Dan Glickman [chairman of the Subcommittee on Transportation, Aviation, and Materials] presiding.

Present: Mr. Volkmer, Mr. MacKay, Mr. Lujan, Mr. Carney, Mr. Chandler and Mr. McCandless.

Mr. GLICKMAN. Good morning. We will begin.

Today the two subcommittees with jurisdiction over NASA—the Transportation, Aviation, and Materials Subcommittee which I chair, and the Space Science and Applications Subcommittee chaired by Mr. Volkmer, who will be here shortly—will join together for the purpose of hearing testimony on certain aspects of the fiscal 1985 NASA authorization that are common to our respective jurisdiction over NASA's programs. Normally we meet separately to consider the various aeronautics and space programs being proposed by NASA. But today we will be reviewing general provisions of the authorization bill and the budget request for institutional programs and construction of facilities—all subjects that overlap our two areas of responsibility.

Mr. Lujan, do you have any remarks?

Mr. LUJAN. Yes, Mr. Chairman, I just have a short opening remark. First of all, welcome to the witnesses this morning. Last year we had hearings on the legislation on the need for more emphasis on science and math education. And of course this is a subject of great interest to all of us. I believe there is more involved in encouraging students' interest in science and math than just sending more federal dollars to the state. It probably means looking at mechanisms or seeing to it that schools and universities have the necessary equipment. It also means improving interest by students by making various career opportunities visible, and the fact that NASA is working to do those two things especially delights me. So I am pleased to have the opportunity to discuss those things.

Mr. GLICKMAN. Thank you, Mr. Lujan; and with all the statements that Mr. Volkmer, Mr. Carney, or anybody else who wants to make an opening statement, will be made a part of the record.

[The opening statement of Mr. Carney follows:]

OPENING STATEMENT OF HON. WILLIAM CARNEY

Thank you, Mr. Chairman, I join the chairman in welcoming you gentlemen here this morning, I look forward to hearing your testimony on what I believe is a very important aspect of NASA's budget. We spend a lot of time debating NASA's programs; yet we often overlook one of the most important elements on NASA's success—namely, the staff and facilities.

Your success in attracting recent engineering and science graduates to join NASA's technical staff is particularly good news this year, and I hope that this infusion of new talent will be allowed to continue.

I am somewhat concerned that the requirement to reduce the number of GS–11's through 15's might have an adverse effect on these efforts. That is the grade range that includes the preponderance of your technical staff, which is so essential if you are to maintain the capability to do the innovative, basic research which I believe is NASA's primary responsibility. I am particularly concerned that your ability to retain the talented young engineers and scientists that you have recently been able to hire could be seriously affected. I will be interested in hearing how you address this potential problem.

I'm sure you gentlemen have much to tell us this morning about NASA's program management plans and proposed new facilities, so I won't take any more of your time. Again, I welcome you and I look forward to your testimony.

Thank you.

Mr. GLICKMAN. Our first witness is Neil Hosenball, general counsel of NASA.

It's a pleasure to have you here. Your statement is pretty short, so go ahead and read it.

Mr. HOSENBALL. Let me go ahead and read my very short statement.

Mr. GLICKMAN. What a pleasure to have a one-page statement. I must tell you that Hubert Humphrey once said that the problem with Americans, especially American politicians, is that everybody wants to put all their ideas on one sheet of paper, and Hubert set out to prove that that was not the norm in politics, but in your case I think it makes a lot of sense.

Mr. HOSENBALL. It reminds me, astronaut Joe Allen, in introducing me to an AIAA section down in Houston, to a bunch of engineers, told a story about 4 years ago, and I've been telling it around town and others have picked it up, about the balloonist flying over your great State of Kansas who got lost up in the clouds. They decided they better find out where they were, so they went down and they saw a farmer on the ground. They figured they would call down to him, and they called down to him and said, "Where are we?" He said, "In a balloon."

They thought they would try again and they said, "Well, where are you?" "I'm on the ground." Then they floated back into the clouds. One balloonist turned to the other balloonist and said, "Gee, it's too bad we ran into a lawyer." [Laughter.]

The other balloonist said, "How come you knew he was a lawyer?" "Well, his answers were correct, concise, and contained no useful information whatsoever." [Laughter.]

So I hope my statement is better than that.

STATEMENT OF S. NEIL HOSENBALL, GENERAL COUNSEL, NASA

Mr. HOSENBALL. Mr. Chairman and members of the subcommittee, I am pleased to appear before you once again to testify on the one substantive change in the fiscal year 1985 NASA authorization legislation.

In section 7 of the bill submitted by the Administrator to the Speaker of the House, but which is now section 6 of the bill introduced by Chairman Fuqua, we are proposing an amendment to the Space Act which would authorize NASA to dispose of personal property which has been on loan for research or teaching purposes for an extended period of time to universities and nonprofit organizations. Every year we ask them to certify they are still using the equipment as agreed to, in order to renew the loan. Since NASA does not anticipate that we will have a need for these items again, and since the schools and other organizations do have need of them, we are proposing language that would allow the Administrator of NASA to transfer title to these items of personal property. Part of the conditions of the transfer would be that the item had been at the educational institution or nonprofit organization for 2 years or more, and that it is still being used for the research and educational purposes for which it was intended to be used. This effort would complement the national goal as well as the NASA goal to improve math and science education and the overall intent of the Space Act as set forth in section 102.

This language has been cleared with the General Services Administration and the Office of Management and Budget and has their approval. We certainly hope that you would look favorably on this proposed change.

I would like to mention that there is a technical change in this year's bill. That is that there are now four categories of authorization of appropriations in section 1. After the research and development paragraph is a new paragraph, "Space Flight Control and Data Communications," which separates the operational aspects of the space transportation system and tracking and data from research and development. This category was first used in the fiscal 1984 appropriation act, and will be used in this year's appropriation act, and we believe the two acts ought to be consistent in both authorization and appropriation.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Hosenball follows:]

TESTIMONY OF S. NEIL HOSENBALL, GENERAL COUNSEL, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman, Members of the Subcommittee, I am pleased to appear before you once again to testify on a substantive change in the FY 1985 NASA authorization legislation. In Section 7 we are proposing an amendment to the Space Act which would authorize NASA to dispose of personal property which has been on loan for research or teaching purposes for an extended period of time to universities and non-profit organizations. Every year we ask them to certify that they are still using the equipment, as agreed to, in order to renew the loan.

Since NASA does not anticipate that we will have a need for these items again, and since the schools do have need of them, we are proposing language that would allow the Administrator of NASA to transfer title to these items of personnal property. Part of the conditions of the transfer would be that the item has been at the eductional institution or nonprofit organization for two years or more, and that it is still being used for the research and educational purposes for which it was intended to be used. This effort would complement the national goal to improve math and science education, and the overall intent of the Space Act as set forth in Section 102.

This language has been cleared with the General Services Administration and the Office of Management and Budget and has their approval.

We hope that you will also look favorably on this proposed change.

Mr. GLICKMAN. Thank you.

Coming from central Kansas, we have a facility called the Kansas Cosmosphere. You may be aware of that; I don't know. Believe it or not, it is the second or third largest receptacle in the country, of NASA educational related equipment, and I assume that this would be the kind of facility that you're talking about? It's a nonprofit place.

Mr. HOSENBALL. Yes, sir. We've made these loans to universities; we've made them even to school districts. We've also made them to similar organizations as the one that you've mentioned, where they can be used both at the college level, the university level as well as other nonprofits that are getting children interested, particularly in science.

Mr. GLICKMAN. The kind of property you're talking about is what?

Mr. HOSENBALL. Oh, I asked for a partial list. There are microscopes, for example, and the accessories that go along with them. Remember, this is used equipment. Before we do make it available, anything over $1,000 is screened within NASA to see if it can be used at our other installations, so this is used equipment and some of it had been there for quite some time. We have vacuum leak detectors, wave form generators, oscilloscopes, the kind of scientific equipment that would be used.

Mr. GLICKMAN. What about uniforms, space suits?

Mr. HOSENBALL. No, not to my knowledge. No.

Mr. GLICKMAN. Well, what about vehicular equipment, some of the old capsules that were flown?

Mr. HOSENBALL. Well, that's done under a different program. That we do generally through the Smithsonian, if they are what we call an artifact, and they are in fact given on loan after clearing it with the Smithsonian to things like the space museum in Huntsville, probably the center that you have mentioned, and other museum kind of activities.

Mr. GLICKMAN. Yes, but they're not covered under—you're talking about smaller personal property items, then?

Mr. HOSENBALL. Yes. Basically, yes.

Mr. GLICKMAN. Is this a one-time adjustment that you think you need, or is this something that would be in the permanent statute?

Mr. HOSENBALL. We would like it in the permanent statute. The stuff that we would loan out today would not become available for 2 years under this statute. We would like to continue the program and make it available to these organizations as equipment becomes used and replaced but is not needed elsewhere in NASA, to turn it over to them on loan, see how they use it, and at the end of 2 years if they want to keep it permanently, to make it available to them, so we would like to keep it a permanent program.

Mr. GLICKMAN. OK. Well, I mean, the more that you can provide that access by nonprofit institutions, higher education, to space-related actvities, aeronautics-related activities, the more support you are going to have in the private sector and among the public for the activities and the more learning that will occur, so I don't see any problem with this at all.

Let me ask you this: The last paragraph has to do with the separation of our categories in authorization to conform with an appro-

priations bill. Is that now a permanent way that you're going to separate out space flight from——

Mr. HOSENBALL. Yes, sir. Unless the Congress makes some other changes, that's the way we would propose to do it in the future.

Mr. GLICKMAN. I mean, is that more of a form over substance type of change? Is there anything significant in that change?

Mr. HOSENBALL. No, it is both a form and it does have some substance. There are some statutes that require us to spend some money for some small business programs. We're required to spend it. It's also a ceiling, and it's basically on what should be research and development, not on operations, so we have broken out—actually the House committee last year, the House Appropriations Committee broke it would so that it would be clear in the future that that should only apply to what is actually our research and development activities, and not to the moneys that are needed for operations.

Mr. GLICKMAN. Just one final question: What about other legal issues? Are you involved in any other major legal issues that we should be aware of? For example, the disputes that we had in negotiating agreements with the Pentagon in connection with the shuttle, where do we stand on all of that?

Mr. HOSENBALL. Well, the disputes we have within the Government are usually settled either by discussions between both agencies, and if we can't get a resolve there it goes to the President. We have that mechanism in place in this administration under the Space Interagency Group, which I am sure you are aware of. That is a mechanism that has been used and I think has worked very well in any arguments or disputes or at least discussions where we can't reach agreement with another agency in the space area, so I don't think we need anything there at all.

Mr. GLICKMAN. What about—now let me go back again: Any major legal problems that NASA is facing now?

Mr. HOSENBALL. No. We are or we will, like we did when it appeared the shuttle was going to become operational, when we have the—they have gone through the space station definition and we see who is going to participate in that activity we are going to, before the definitional stage is over, do a review like we did with shuttle. In fact, we came up here and got several pieces of legislation that we thought was necessary, going from an expendable to a reusable vehicle, and I suspect that either me or my successor will be up here at some time asking possibly for some additional legislation. Right now we don't see any need for special legislation.

Mr. GLICKMAN. How about litigation? The problem which existed, for example, in the last space shuttle when there were inoperative satellites, is there anything there that you are exploring with respect to some of the contractors?

Mr. HOSENBALL. No. As you are aware, we are still looking to find out what happened and how to fix it. The thing is currently fluid and at this stage, certainly, with these hearings I am not prepared to suggest that we need anything. What will come out of that investigation and how we will be involved—although I don't see how we will be involved, with the successful deployment that we accomplished—but there may be some suggestions from others that

may say we need some additional legislation. Right now I don't see the need for it.

Mr. GLICKMAN. But your office has not been approached with respect to taking any action against any third parties?

Mr. HOSENBALL. Absolutely not.

Mr. GLICKMAN. Final question: The issue of warranties, as you know that has become a very controversial subject up here with respect to the Defense Department getting warranties from defense contractors with respect to the usefulness and the workability of items supplied to the Government. With the burgeoning space shuttle program, it's taking on more of an operational orientation to it. Do you think that there are parallels there, that maybe some of these contractors who are involved—and the taxpayers are paying multibillions of dollars to get these vehicles up in the air—ought to have some warranties to their products they supply you?

Mr. HOSENBALL. Well, during an earlier job with NASA I was Assistant General Counsel for Procurement, so I am somewhat—very familiar with the procurement process. All I can do is really express a personal opinion, because it has not come up with the agency and I cannot speak for the Administrator in this area, but based on my experience I think you have to be very careful in imposing warranties in the kind of business we're in, certainly in the space business. We're pushing the state of the art. There are uncertainties in the space business.

I have some particular concern that when you start asking for warranties, you're going to have a very substantial impact on small business. The risks they would take under the warranties would be great, and I think we would find that the small businessman faced with a warranty may very well not be willing to do business with the Government, which is contrary——

Mr. GLICKMAN. Well, I would just say that that's exactly what Mr. Weinberger has told Congress.

Mr. HOSENBALL. And I am inclined to agree with Mr. Wineberger, if you will.

Mr. GLICKMAN. Yes. I just wondered, do you have the legal authority now to insist on warranties and, let's say, agreements between you and contractors?

Mr. HOSENBALL. Oh, yes, sir. Yes, sir. We by contract could require warranties. We wouldn't need any legislation, and there is a provision like there have been in the past for obtaining warranties. You of course take into consideration the cost of that warranty. You don't get—there is nothing free. If you want that warranty, you're exposing yourself and have to charge for it.

Mr. GLICKMAN. But that's a policy decision on our part, to decide whether we want to impose that issue. I just wanted to know from a legal standpoint. There is nothing whatsoever in the statute that would prevent you from putting warranty language in contracts that you have with contractors?

Mr. HOSENBALL. Absolutely.

Mr. GLICKMAN. Thank you.

Mr. Lujan?

Mr. LUJAN. Yes. I will yield to Mr. Carney.

Mr. CARNEY. Thank you, Mr. Lujan.

Mr. Chairman, we have an ED and A subcommittee markup, and I would just ask unanimous consent that my opening remarks be placed in the record immediately following those of Mr. Lujan.

Mr. GLICKMAN. Your remarks have already been placed in the record right up in the beginning after mine, I think.

Mr. CARNEY. Oh, you're way ahead.

Mr. GLICKMAN. Fine. I accept that.

Mr. CARNEY. I thank you, Mr. Chairman. It just proves what I've always been saying: that as far as subcommittee chairmen go in the House of Representatives, Dan Glickman is one of the most alert and well-equipped that we have. Thank you, Mr. Chairman. And he's a good guy no matter what they say about him. [Laughter.]

Mr. GLICKMAN. Mr. Lujan?

Mr. LUJAN. Thank you.

Mr. Hosenball, you're going to lose your standing in the legal community. The statement is concise and correct and it's also factual.

Mr. HOSENBALL. Thank you very much, sir.

Mr. LUJAN. In these transfers of equipment to the universities, will we have any trouble with the regular procedure that's followed now by GSA, that it has to be offered to another Federal agency—well, first of all, I imagine, to other laboratories——

Mr. HOSENBALL. This legislation gives us the authority to avoid that procedure, and that's why we are basically asking for it.

Mr. LUJAN. What kind of equipment are we talking about?

Mr. HOSENBALL. I read a—vacuum gages in some cases; a moisture balancer; a carbon/hydrogen analyzer; an atomic timer; a gas chromatograph; a human performance tester; a vacuum tube voltmeter. It's scientific equipment that either has been replaced by new equipment——

Mr. LUJAN. But it's all used by the time they get it at the university?

Mr. HOSENBALL. Oh, yes, very much so.

Mr. LUJAN. Why don't we give it to them right up front, rather than say, "Here you are for 2 years," and——

Mr. HOSENBALL. Well, I think we want to make sure that they need it and they're actually going to use it and not just take it and then 6 months later put it on the shelf somewhere, so we think a 2-year period is a reasonable period.

Mr. LUJAN. It's probably a good idea.

Let me ask you about a couple of legal things that have gone on in NASA and see if those things are completed. One, we had the inspector general and I guess your office involved in that whole Rockwell allegation, didn't we?

Mr. HOSENBALL. Yes.

Mr. LUJAN. Is that all finished, all done——

Mr. HOSENBALL. Yes, sir.

Mr. LUJAN [continuing]. Resolved?

Mr. HOSENBALL. Yes. Well, I think there is still some ongoing IG activity, but——

Mr. LUJAN. Some what? Pardon me.

Mr. HOSENBALL. I think there is still some ongoing IG activity, not from the point of view of any criminal prosecution but to see if

there are any additional amounts that might be owed that were not covered as a result of the agreement reached by the Department of Justice and——

Mr. LUJAN. Is Justice all done with their part of it?

Mr. HOSENBALL. Yes, sir, that is all done.

Mr. LUJAN. Yes.

Mr. HOSENBALL. But I do believe there is still some ongoing IG, and I would suspect that the IG does cover Rockwell and looks at Rockwell, since they are a major contractor of ours.

Mr. LUJAN. Yesterday we got in rather deeply into the whole TDRSS contract. You had to renegotiate it, take back some time, or all the time, rather; had to pay some additional sums for cutting out the commercial sector of it.

Mr. HOSENBALL. The commercial part, right.

Mr. LUJAN. Are you all done with that? Is that——

Mr. HOSENBALL. Yes, sir. We're all done with that restructuring. There are some claims as a result of shuttle delay and some other things that are under the process of negotiation now, some of those kinds of——

Mr. LUJAN. You mean we're going to have to pay them more because of the delay?

Mr. HOSENBALL. Yes, sir. Yes, sir, we will. These are claims that resulted from the delay in the launch originally, and of course now we have some additional delay as a result of the IUS's that I'm sure you are familiar with, so there are some fairly substantial claims that are under negotiation right now. I don't know the exact details. That's being done out at Goddard. We do keep abreast of what's going on, and they have a team currently in the process of negotiating a settlement of those claims with Spacecom as well as TRW, the prime—the major subcontractor.

Mr. LUJAN. I asked what I guess is an unfair question yesterday, that in retrospect should we have gotten into that kind of a contract, and the only reason—and I'm not going to ask the same question—the only reason that I raised that question is for the future, you know, on other things that may come along and maybe some lessons that we learned from it, and maybe do it the same way or——

Mr. HOSENBALL. It was based on the assumption, the contract that we entered into was based on the assumption that the development of that satellite, with the commercial as well as the tracking data part, was well within the state of the art, and that assumption was wrong, looking back, in hindsight. We think the next time we have to do it, we better make sure that we're right in our assumption.

Mr. LUJAN. Is it, then, the practice of NASA that you go into something like that and into fixed contracts only when it's within the state of the art?

Mr. HOSENBALL. Yes, sir.

Mr. LUJAN. Generally you go cost-plus if it's not within the state of the art?

Mr. HOSENBALL. That's right, because otherwise you're going to have changes and that, once you start massive, large numbers of changes you've destroyed that fixed price contract. You're always in the process of negotiating new prices, and it doesn't work in

R&D where you really do have a research and development program. The assumption was wrong, and I think we've learned some things from it and I think we'd be a lot more careful in the future in not selecting the right contract vehicle to carry out the program.

Mr. LUJAN. Why, then, would—why was that assumption made, and then it turned out that that wasn't the case, because it——

Mr. HOSENBALL. Well, it turned out to be a lot harder job than people thought it was.

Mr. LUJAN. On paper it was a workable thing——

Mr. HOSENBALL. That's right. That's right.

Mr. LUJAN [continuing]. But then actually getting down——

Mr. HOSENBALL. That's right. It turned out to be a lot harder technical job than people assumed.

Mr. LUJAN. Did they, did Spacecom have their own people doing the engineering and science and all that, or does NASA do it for Spacecom?

Mr. HOSENBALL. No, sir. TRW is doing it under a subcontract with Spacecom. We have an office that does monitor the progress and follows the spacecraft to make sure that it will work, and there are continual meetings between our people and the Spacecom people and the TRW people to see what the status is, what the problems are, and how they can best be solved at the lowest cost, if you will.

Mr. LUJAN. Because there was some belief that the reason it was done that way was to get it off the budget—because we always have budget constraints, it seems like—to get it off the budget. That was the way, the mechanism used to get it done, and of course the bill gets passed on later on when we have no choice. I won't ask you to answer that question.

Thank you, Mr. Chairman.

Mr. GLICKMAN. Thank you.

Mr. McCandless, do you have any questions?

Mr. MCCANDLESS. Thank you, Mr. Chairman. I think you pretty well covered the waterfront for this particular witness, in your own inimitable way.

Mr. GLICKMAN. Thank you very much.

Mr. Chandler, do you have any questions?

Mr. CHANDLER. No, thank you.

Mr. GLICKMAN. Thank you. We appreciate your testimony.

Mr. HOSENBALL. Thank you very much.

Mr. GLICKMAN. Our next witness is Mr. John Boyd, Associate Administrator for Office of Management at NASA.

STATEMENT OF JOHN BOYD, ASSOCIATE ADMINISTRATOR, OFFICE OF MANAGEMENT, NASA, ACCOMPANIED BY C. ROBERT NYSMITH, ACTING DEPUTY ADMINISTRATOR, OFFICE OF MANAGEMENT; AND CHARLES TULIP, DIRECTOR, INSTITUTIONAL PROGRAM ANALYSIS DIVISION, OFFICE OF THE COMPTROLLER

Mr. BOYD. Thank you, Mr. Chairman.

I would like to introduce Mr. Nysmith, on my right, who is my deputy; and Mr. Tulip, on my left, from Code B, who knows all the details of the numbers.

Mr. GLICKMAN. OK.

Mr. BOYD. As you may know, I have just arrived here in Washington from one of the field centers, in this position, and it's really a pleasure and a privilege to be here to testify this morning, not having done this before.

Mr. GLICKMAN. We'll be real easy on you. We're easy people up here. [Laughter.]

Mr. BOYD. I would like to give you an overview, and I apologize for not having a one-page statement, but I couldn't quite get this on one page. I would like to give you an overview of the National Aeronautics and Space Administration's Research and Program Management authorization request and to review some other matters related to the management of the NASA institution.

The research and program management appropriation provides funding to maintain the in-house capability necessary to accomplish NASA's research and development programs. About 70 percent of these funds are required to pay the approximately 22,000 civil service salaries. These civil servants make up a significant portion of the Nation's aerospace engineering and technology core manpower capability. The remaining 30 percent of the requested funds provide for the necessary institutional supplies, materials, equipments, and travel to support our staff and operate our centers.

Before addressing NASA's budget for 1985, I want to discuss with you changes from the 1984 budget request presented to you last year. Of the 1984 research and program management request of $1,247,500,000, $1,238,500,000 has been appropriated. This is a reduction of $9 million. We are requesting a supplemental appropriation of $20 million to provide for the $28,300,000 cost of civil service pay and benefit increases in 1984. This supplemental excludes $8.3 million in estimated pay cost requirements that the Agency plans to absorb through administrative action in 1984. If $20 million is appropriated, the 1984 plan for R&PM will then be $1,258,500,000.

The $9 million 1984 appropriation reduction made by Congress and the $8.3 million absorption of increased pay and benefit costs, for a total of $17.3 million, will be accommodated largely through deferring and delaying expenditures in all areas of R&PM. In personnel and related costs, savings will be achieved by rephasing of career development adjustments and a change in the mix of temporary programs and the use of overtime and holiday premiums. In operation of installation, cost reductions will be achieved by the delay and deferral of purchases of supplies, equipments, and contractual effort.

The largest single alteration will be in the standard level user charge paid to GSA for 1984. Because of the changes brought about through legislation, the 1984 payment will be about $2.4 million less than planned. All of these savings are applied to meeting the $17.3 million reduction in 1984. Although these reductions will place some burden on NASA in providing adequate institutional support to the research and development programs, the reductions are designed and planned to minimize this adverse effect.

In 1983, as I am sure you have heard several times, NASA was able to recruit a larger number of recently graduated—"freshouts"—scientists and engineers than in the past few years because

of the stability of the civil service ceiling, which is really very important to us. This infusion of "fresh-outs" has reversed the rise in average age of the technical work force and, if continued through 1984 and 1985, will help keep the technical work force vital and, I believe, contribute very much to the long-term health of that work force.

The 1985 budget estimate of $1,331,000,000 is an increase of $72,500,000 over the 1984 current estimate, and it provides for personnel and related cost of 22,000 full-time equivalent civil service workyears, and a minimum level of travel to support agency missions and programs, with a modest increase to allow greater technical development travel by the NASA scientists and engineers, an area we think is vital to ensure their currency in their programs. In addition, the 1985 request contains a $10 million augmentation in operational maintenance designed to bring actual maintenance more in line with the needs of the NASA physical plant. That is very important to us, and I will speak to it more later.

Now, let me briefly summarize by functional category the research and program management appropriations requested for 1985:

Personnel and related costs of $935,928,000: This estimate for personnel and related costs is based on the 22,000 full-time equivalent civil service workyears, the same work force as 1984. The increase of $22,982,000 in personnel and related costs funding from 1984 to 1985 is a result of the following: The full year cost of 1984 pay and benefit increases, which was in effect for only three-fourths of the year in 1984; the normal costs associated with within-grade and career development, merit pay, and so forth; an additional paid day in 1985; and a partial offset as part of the President's plan to reduce the size and cost of the GS/GM 11 through 15 work force Governmentwide.

The travel of $28 million is quite important to us. Because the vast majority of NASA funds are spent out of house, travel for both programmatic and management purposes is integral to the effective and economic accomplishment of program objectives. In addition, because NASA's civil servant work force is so heavily technical—over 50 percent are degreed scientists and engineers—the technical development travel is very, very important for the interchange of information. In 1985, the $2.3 million increase in travel over 1984 is made up of two parts: An increase associated with expected higher travel costs, and an augmentation of $800,000 in scientific and technical development travel to increase the opportunities for creative growth and development for our research personnel and improve the exchange of information, I think to the mutual benefit of the staff and the scientific and engineering community at large.

The operation of installation of $367,072,000 provides for anticipated changes in price levels of support service contractor wage rates and utility rates; an alteration of the funding plan for some reimbursable activities; and in price levels for supplies, materials, equipments, and minor contracts. There is also the augmentation I mentioned earlier of $10 million in preventive operational maintenance activities in the facilities service subfunction.

In summary, the 1985 budget requirement of $1.331 billion is to provide for 22,000 full-time equivalent civil service workyears and to support the activities at the eight NASA installations as well as at headquarters, consistent with the research and development, the space flight, the control and data communications, and the construction of facilities plans. I believe it is a lean request that supports a level program, except for modest increases in the technical development travel that I mentioned and a needed increase in operational maintenance.

It should be recognized that we have based our estimates on the assumption that rate increases will be significantly lower than we have experienced over the past several years. Even though we have based our 1985 utility estimate on lower rate increases, the unit cost for utilities will continue to rise faster than in other areas. We are attacking this utility problem in a variety of ways, including a continuous conservation program which, since 1973, as you probably know, has reduced our energy consumption by about 38 percent, even though new facilities and increased program activities are coming online. This concludes my statement on the research and program management budget, but there are a couple of other institutional things I would like to highlight for you.

Last year, as I recall, we discussed several productivity improvement actions. I would like to highlight one or two of those for you.

In the past year, NASA initiated a focused productivity improvement and quality enhancement effort aimed at stimulating greater agency effectiveness. This effort involves our contractors as well as our own inhouse work force. We have already started several long-term initiatives that promise good payoff, and can report example accomplishments stemming from various efforts in NASA. This effort involves the introduction of the quality circle concept, which I'm sure you have heard some about; revitalizing our employee suggestion program; streamlining to some degree our administrative processes; expanding NASA's impact in making math and science interesting in schools; and some initiatives to develop contractual approaches that will lead to better team efforts.

Some examples of our first-year efforts to stimulate increased NASA productivity are the initiation of about 60 pilot NASA employee teams or quality circles which will encourage greater employee actions toward improving NASA productivity. One problem identified and solved, for example, by the NASA employee team involved the configuration of a vacuum pump system for model development at Langley, which is our pilot center for this, which will translate into more efficient operations. I think the very fact that you can sit down with people like this and have them interface with each other and understand the problems at hand gives you many more ideas that you can pursue to solve these kind of problems.

Attempts to streamline our administrative processes and thereby increase the time available for our professionals to spend on direct research and development has resulted in actions to reduce the lead time for procurement and the amount of paperwork by approximately 20 percent. In addition, through our efforts in office automation, we realized significant savings in time in preparing our program planning and budget information. An example of that

is, the automation of the annual program operating plan at Langley has reduced the manhours required in the logistics of just compiling this information for OAST from about 140 to 24 hours. In addition to NASA's effort to improve the productivity and efficiency of our work force, the 1985 budget request reflects the impact of several Government-wide management improvement initiatives. These include a reduction in the number of personnel specialists; greater use of the private sector in making travel accommodations; improved coordination of our administrative ADP systems, and a review of our inhouse printing operations. NASA will continue to participate in these and other management improvement initiatives that are developed, and will continue to improve the productivity of its work force and operations.

A brief comment on equal opportunity: I think we have made significant progress in the area of equal opportunity in fiscal 1983. Our hiring opportunities increased significantly, a total of 1,695 hiring opportunities compared to about 982. The number of minorities and nonminority women hired by NASA also increased significantly; 392 minorities were hired in 1983 as compared to about 186 in 1982, and 470 nonminority women were hired in 1983 compared to 309 in 1982.[1]

In another area that we have been working on quite actively, the number of minorities in the higher GS/GM grades of 14 and above increased by about 21. This included the gain of 4 minorities in the SES field. The number of nonminority women in GS–14 and above increased by 20.

As you know from Mr. Beggs' testimony, one of the agency's eight major goals and a major institutional goal is provide for our people a creative environment and the best facilities, support services, and management support so they can perform with excellence NASA's research and technology program as well as our operational responsibilities. This goal recognizes that NASA's civil service work force is the critical element essential to accomplishing NASA's aeronautics and space mission.

This has been well-recognized in many studies, including the recent one carried out by the Office of Science and Technology Policy under David Packard. This study explicitly recognized the importance of Federal laboratories and their capability to the national security and to our economic health. In another interesting aside, they felt that they were very critical and important to training new young scientists and engineers.

As you know, many of our inhouse capabilities at NASA are unmatched anywhere in the world. Our wind tunnels and flight simulators are the best in existence, and are heavily used to support both military and commercial airplane developments. The NASA computational complex is probably the best or close to the best in the world. Together, the facilities and staff at these NASA centers represent a unique and valuable resource.

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[1] The numbers in the transcript are inaccurate according to the witness who submits corrected numbers so that the last two sentences should read. "Our hiring opportunities increased significantly, a total of 1,695 hiring opportunities compared to about 899. The number of minorities and nonminority women hired by NASA also increased significantly: 393 minorities were hired in 1983 as compared to about 186 in 1982 and 421 nonminority women were hired in 1983 compared to 309 in 1982."

On an occasion in last August/September, just before I came back here, I went to each of the eight centers in a period of about 11 days. While it's a fairly tiring effort, it was a very impressive thing to see in a short period of time, and I am sure some of you may have done something like that yourselves.

One more point: The opportunity that we had to hire 600 "fresh-out" scientists and engineers in the past year has really helped to revitalize our staff. Incidentally, of those 600 about 37 percent were minorities and women. The environment we provide is critically important to permit us to attract these young people, who by their very presence stimulate that environment. We need to continue to do this through the next several years, within our civil service ceiling, to provide the cadre of scientists and engineers needed to pursue our future major projects and programs.

I have personally talked to many of these young people, and there is no question in my mind that we have been able to get some of the very best young people in the country, and I think we have gotten them because we have unique facilities. We have people who are leaders in the world of research and technology, and the constantly challenging programs that you permit us to pursue is something that really is very important to them. I had breakfast with about 40 of them 2 weeks ago out on the west coast. Their questions are not at all narrow, like they came from physics, aeronautics, mechanics, civil engineering, you name it, but their questions were much broader. In fact, they were some of the questions I have heard you pose here, as a matter of fact, in some of the hearings—a very bright group of young people. So I can't overemphasize the significance that this vigorous and youthful work force has on the health of the institution.

Mr. LUJAN. If you will excuse me, I was just wondering what you were going to say about the difference in questions between those kids and here. [Laughter.]

I was just worried for a minute there.

Mr. BOYD. I won't do that in the hearing.

Mr. GLICKMAN. You've been here for a short time but you have good judgment. [Laughter.]

Mr. BOYD. Thank you.

I have to repeat one more time, the single most important ingredient that we have in NASA to conduct our programs are our people. They generate the new facilities. They generate the new ideas. They are key, and I think we have made an exceptionally good start in this group of 600 this time. I want to emphasize once more the importance of the R&PM budget to the overall conduct of NASA's research and technology operational activities. Because all of our civil service people and their travel is funded from R&PM, the inhouse research and the monitoring of the out-of-house contractual work would not be possible without it.

The fiscal 1985 request provides for a continuation of a level civil service complement, an adequate level of travel, and a very modest increase in preventive operational maintenance. We hope the request is fully authorized and appropriated.

I would be glad now to answer any questions you may have.

[The prepared statement of Mr. Boyd follows:]

HOLD FOR RELEASE UNTIL
PRESENTED BY WITNESS
MARCH 1, 1984

STATEMENT
OF
JOHN W. BOYD
ASSOCIATE ADMINISTRATOR FOR MANAGEMENT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS, AND
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

Messrs. Chairmen and Members of the Subcommittees:

It is my pleasure to present for you today an overview of the National Aeronautics and Space Administration's (NASA) 1985 Research and Program Management (R&PM) Authorization request, and to review other matters related to the management of the NASA institution.

The Research and Program Management Appropriation provides funding to maintain the in-house capability necessary to accomplish NASA's research and development (R&D) programs. About 70 percent of these funds are required to pay the approximately 22,000 NASA civil servants. These civil servants make up a significant portion of the Nation's aerospace engineering and technology core manpower capability. The remaining 30 percent of the requested funds provide for the necessary institutional supplies, materials, equipment, utilities, services, and travel to support our staff and operate our Centers.

FY 1984 Budget Changes

Before addressing NASA's Budget Request for 1985, I want to discuss with you changes from the 1984 Budget presented to you last year. Of the 1984 Research and Program Management request of $1,247,500,000, $1,238,500,000 has been appropriated; this is a reduction of $9 million. We are requesting a supplemental appropriation of $20,000,000 to provide for the $28,300,000 cost of civil service pay and benefit increases in 1984. This supplemental excludes $8.3 million in estimated pay cost requirements that the Agency plans to absorb through administrative action in 1984. If $20 million is appropriated, the 1984 plan for R&PM will be $1,258,500,000.

The $9.0 million 1984 appropriation reduction made by Congress and the $8.3 million absorption of increased pay and benefits costs (for a total of $17.3 million) will be accommodated largely through deferring and delaying expenditures in all areas of R&PM. In Personnel and

Related Costs, savings will be achieved by a rephasing of career development adjustments and a change in the mix of temporary programs and the use of overtime and holiday premiums. In Operation of Installation, cost reductions will be achieved by the delay and deferral of purchases of supplies, materials, equipment, and contractual effort. The largest single alteration will be in the Standard Level User Charge (SLUC) paid to GSA for 1984. Because of changes brought about through legislation, the 1984 SLUC payment will be $2.4 million less than planned. All of the SLUC savings are applied to meeting the $17.3 million reduction in the 1984 estimated requirement. Although these reductions will place a burden on NASA in providing adequate institutional support to the research and development programs, the reductions planned are designed to minimize the adverse impact.

In 1983, NASA was able to recruit a larger number of recently graduated (fresh-out) scientists and engineers than in the past few years because of stability in the civil service ceiling. This infusion of fresh-outs has reversed the rise in the average age of the NASA technical workforce, and if continued in 1984 and 1985, will help keep the technical workforce vital, and contribute to the long-term health of that workforce.

FY 1985 Estimate

The 1985 budget estimate of $1,331,000,000, an increase of $72,500,000 over the 1984 current estimate, provides for: the personnel and related costs of 22,000 full-time equivalent civil service workyears; a minimum level of travel to support Agency missions and programs, with a modest increase to allow greater technical development travel by NASA scientists and engineers, an area vital to ensure their currency; support service contractors at anticipated wage rates; utility usage consistent with programmatic requirements at projected rates; and supplies, materials, equipment, and other minor contracts and services at anticipated price levels. In addition, the 1985 request contains a $10 million augmentation in operational maintenance designed to bring actual maintenance more in line with the needs of the NASA physical plant.

Now, let me briefly summarize by functional category the Research and Program Management Appropriation request for 1985.

1. Personnel and Related Costs ($935,928,000): The 1985 estimate for Personnel and Related Costs is based on 22,000 full-time equivalent civil service workyears. The same workforce level as 1984. The increase of $22,982,000 in Personnel and Related Costs funding from 1984 to 1985 is a result of the following: the full-year cost of the 1984 pay and benefits increase (which is in effect for only three-fourths of FY 1984); the normal costs associated with within-grades, career development, merit pay, etc; the additional paid day in FY 1985; and a partial offset as part of the President's plan to reduce the size and cost of the GS/GM 11-15 work force Government-wide.

2. Travel ($28,000,000): Because the vast majority of NASA funds are spent out of house, travel for both programmatic and

management purposes is integral to the effective and economical accomplishment of program objectives. In addition, because NASA's civil service workforce is so heavily technical (over 50 percent of NASA's permanent personnel are degreed scientists and engineers) technical development travel is important for the interchange of information. In 1985, the $2,300,000 increase in travel over 1984 is made up of two parts: an increase associated with expected higher travel costs; and an augmentation of $800,000 in scientific and technical development travel to increase the opportunities for creative growth and development for our research personnel, improving the exchange of information to mutual benefit between our staff and the scientific and engineering community at large.

3. Operation of Installation ($367,072,000): The 1985 plan provides for anticipated changes in the price levels of support service contractor wage rates and utility rates; an alteration in the funding plan for reimbursable activities; and in price levels for supplies, materials, equipment, and minor contracts. There is also an augmentation of $10 million in operational maintenance activities in the Facilities Service subfunction. This augmentation will provide for a more adequate level of such activities consistent with the age and the investment in the NASA physical plant. The amounts by subcategory are:

   A. Facilities Services ($198,279,000): The 1985 estimate, an increase of $27,450,000 over the 1984 current estimate, covers anticipated rate and price increases for utilities; support contractor wage rates, supplies, materials, equipment, and minor contractual effort; and the augmentation in operational maintenance activities of $10 million.

   B. Technical Services ($57,765,000): The $5,261,000 increase in 1985 covers anticipated support service contractor wage rates and the costs of supplies, materials, equipment, and minor contractual effort.

   C. Management and Operations ($111,028,000): The $14,507,000 increase in this subcategory is needed to provide for the increased cost of supplies, materials, equipment, and minor contractual effort; the anticipated change in support service contractor wage rates; and to offset the reduction in reimbursements received.

In summary, the 1985 budget requirement of $1,331,000,000 is to provide for 22,000 full-time equivalent civil service workyears and to support the activities at eight NASA installations and Headquarters, consistent with the research and development, space flight, control and data communications, and construction of facilities program plans. It is a lean request that supports a level program, except for modest increases in technical development travel and a needed increase in operational maintenance. The increases in the cost of that level program only cover the growth in the cost of doing business. It should be recognized that we have based our estimates on the assumption that rate increases will be significantly lower than we have experienced over the past several years. Even though we have based our 1985

utility estimate on lower rate increases, the unit cost for utilities will continue to rise faster than in other areas. NASA is attacking the utility problem in a variety of ways, including a continuing conservation program which, since 1973, has reduced our energy consumption by 38 percent even though new facilities and increased program activities are coming on-line.

This concludes my statement on the Research and Program Management Budget. I will now highlight several other institutional items which may be of interest to you.

NASA PRODUCTIVITY AND QUALITY ENHANCEMENT

Last year we discussed several productivity improvement actions. I can highlight some accomplishments in that area.

This past year NASA initiated a focused Productivity Improvement and Quality Enhancement (PIQE) effort aimed at stimulating greater Agency effectiveness. This effort involves our contractors as well as our work force. We have already started several long-term initiatives that promise good pay-off and can report example accomplishments stemming from the various efforts throughout NASA. PIQE efforts involve the introduction of the Quality Circle concept (which we call NASA Employee Teams, NETs), revitalizing our employee suggestion program, streamlining our administrative process, expanding NASA's impact in making math and science more interesting in schools, and initiatives to develop contracting approaches that lead to better team efforts.

Some sample results of our first year efforts to stimulate increased NASA productivity are the initiation of 60 pilot NASA Employee Teams which will encourage greater employee actions toward improving NASA productivity. One problem identified and solved by a NASA Employee Team involved the reconfiguration of a vacuum pump system for model development at the Langley Research Center, our pilot Center for NETs, which will translate into more efficient operations. The NETs have been expanded to each Center for a total of 60. Attempts to streamline our administrative processes, and thereby increase the time available for our professionals to spend on direct research and development, has resulted in actions to reduce the lead time for procurements and the amount of paperwork by approximately 20 percent. In addition, through our efforts in office automation, we have realized significant time savings in preparing our program planning and budget information. As just one example, the automation of the annual program operating plan at the Langley Research Center has reduced the manhours required in the logistics of compiling the OAST POP (Office of Aeronautics and Space Technology Program Operating Plan) from 140 to 24 hours.

At Johnson Space Center improvement was made to the engineering support services contract by installing a Computer Aided Design and Drafting (CADD) system. This has reduced the number of trips to the contractor's facility to review drawings and enhances design review teleconferences which further reduces travel.

We have asked our contractors to join us in improving productivity. To this end we have recently created a NASA/Contractor Productivity

Council whose objectives are to identify impediments to productivity and ways to alleviate them; and to exchange ideas and approaches for productivity and quality improvement efforts. The Council had its first meeting February 28-29, 1984, and we are optimistic it will be a successful addition to our efforts to improve NASA's performance.

GOVERNMENT-WIDE MANAGEMENT IMPROVEMENT INITIATIVE

In addition to NASA efforts to improve the productivity and efficiency of our work force and operations, the FY 1985 budget request reflects the impact of several Government-wide management improvement initiatives. These include a reduction in the number of personnel specialists, greater use of private sector services in making travel accommodations, improved coordination of administrative ADP systems implementation, review of in-house printing operations, and improved cash management. NASA will continue to participate in these and other management improvement initiatives that are developed, and will continue to improve the productivity of its work force and operations.

EQUAL OPPORTUNITY

NASA made significant progress in the area of equal opportunity recruitment in FY 1983. Hiring opportunities increased significantly; a total of 1,695 hiring opportunities as compared to 899 in FY 1982. The number of minorities and nonminority women hired by NASA also increased significantly; 392 minorities were hired in FY 1983 as compared to 186 in FY 1982, and 470 nonminority women were hired in FY 1983 as compared to 309 in FY 1982.

The number of handicapped persons with targeted disabilities hired by NASA also increased. In FY 1983, 27 were hired as compared to 21 in FY 1982. In addition, one Disabled Veteran with 30 percent or more disability was hired in FY 1983.

Nonminority women increased their representation in the work force from 3,651 (17.2%) to 3,891 (17.7%).

Minorities increased their representation in the work force from 2,433 (11.5%) to 2,706 (12.3%). We were able to increase representation in each of the targeted groups.

Handicapped persons with Severe Targeted Disabilities increased their representation in the work force from 161 (0.68%) to 176 (0.74%).

Disabled Veterans with 30% or more disability decreased in their representation in the work force from 108 to 104.

Minorities and women continued to make gains in the mid- and higher-level GS/GM grades and in the managerial/supervisory ranks.

The number of minorities in GS/GM-14 and above increased by 21. This included a gain of four minorities in the SES. The number of nonminority women in GS/GM-14 and above increased by 20.

The number of minorities in managerial/supervisory positions increased by eight. The number of nonminority women in these positions increased by 15.

NASA needs to continue to attract the most talented women, minorities, and handicapped persons to the Agency. Continued emphasis will be given to improve NASA's ability to attract fresh-out engineering graduates and to improve its record in moving minorities and women into middle-management positions. In addition, priority attention will be given to the implementation of the Administrator's objective of integrating the SES and senior management; to the implementation of EO performance accountability standards; and to programmatic activities that contribute to the prevention of sexual harassment in the work place.

As you know, one of the Agency's eight major goals, and a major institutional goal, is to "Provide for our people a creative environment and the best of facilities, support services, and management support so they can perform with excellence NASA's research, development, mission, and operational responsibilities."

This goal recognizes that the NASA civil service work force is the critical element essential to accomplishing NASA's aeronautics and space mission. This has been well recognized in many studies, including the recent one carried out by the Office of Science and Technology Policy under the chairmanship of Dr. David Packard. This study explicitly recognized the importance of federal laboratory capabilities to the national security and to our economic health. As you know, many of our in-house capabilities in NASA are unmatched anywhere else in the world. Our wind tunnels and flight simulators are the best in existence and are heavily used to support military and commercial airplane developments. The NASA computational complex is probably the best or a close second. In space systems development, testing, and operations, many fundamental capabilities are dependent on facilities available only at NASA Centers. Critical to the effective use of these facilities is the expertise and experience resident within the in-house NASA staff. Together the facilities and staff represent a unique and valuable National resource.

The opportunity to recruit 600 fresh-out scientists and engineers in the past year has helped to revitalize our staff. The environment we provide is critically important to permit us to attract these young people who, by their very presence, stimulate that environment. We need to continue to do this through the next several years (within our civil service ceiling) to provide the cadre of scientists and engineers needed to pursue our major projects. I have personally talked to many of these young people, and there is no question in my mind that we have been able to get some of the very best young scientific and engineering people in the nation to join NASA. In large measure because of our excellent facilities, but more important because of our constantly challenging programs which are vitally important to the nation and the world. Further, we have been able to reduce the average age of our technical work force by a significant factor because of our ability to hire these young people. I cannot overemphasize the significance that a vigorous and youthful work force

has on the health of the NASA institution. The single most important ingredient that we in NASA have to conduct our programs are our people!

I want to emphasize once more the importance of R&PM to the overall conduct of NASA's research, technology, development, and operations activities. Because all of our civil service people and their travel is funded from R&PM, the in-house research and the monitoring of the out-of-house contractual work would not be possible without it.

The Operation of Installation funds provide for all our Centers utilities and other base support costs. We are concerned that this support is not further eroded, because if it is, the quality and quantity of our technical effort will suffer. We are seeking to ensure the maintenance of our plant with the augmentation in Operation of Facilities. The FY 1985 request provides for the continuation of a level civil service complement, an adequate level of travel, and a modest increase in operational maintenance. We hope the request is fully authorized and appropriated.

I am ready to answer any questions you may have.

Mr. GLICKMAN. Thank you for your good statement. I want to say, and I am sure I speak for the other members who concur that the strength of the agency is its people. I think that your statement reflects a note of optimism about the quality of people; that you have had good success in attracting new people; you have had good success in expanding your affirmative action programs, so that we bring previously disenfranchised groups of people into positions of power and authority, not just at low-grade positions, which is what you said today.

Mr. BOYD. And the encouraging thing in getting the 37 percent of the new folks in, is that this is the beginning of another pipeline that we hope will continue.

Mr. GLICKMAN. Yes. What does it look like for this year for hiring trends and targets, particularly for young scientists?

Mr. BOYD. I would say this year we will be somewhat less than last year but it will probably be on the order of 275 to 300 new "fresh-outs" that we will get during fiscal 1984. The program is active. I do think that in fiscal 1983, when we were quite successful, we were successful for several reasons that I mentioned about the NASA programs.

I think we were also successful because the economy was a bit down. I went to several universities myself, and the students at MIT and places like that, Cal Tech, for the first time didn't have 10 offers in their hands. They had two or three and NASA was one of them, and they became—that was one area of interest. It will be interesting to see if we continue that in 1984. Two-thirds of the people we made offers to in 1983 accepted our offers. That's a very high percentage. To get to 600, we made about 900 offers.

Mr. GLICKMAN. What about the—we've talked about the retention problem, the stealing away from the Boeings and Rockwells and, you know, other high-tech companies at twice and three times the salary.

Mr. BOYD. Yes.

Mr. GLICKMAN. How did you do last year on retention?

Mr. BOYD. We did very well last year but I think, again, the industry was in a bit of—well, I won't call it a slump but they weren't making as many offers to our people.

Let me say we have done two or three things that we hope will help that situation. We have always had a very good educational program that is compatible with the young engineers, to have them take advanced courses and what have you. They are always interested in doing that. We set particularly this year, because we had a fair number of "fresh-outs," some mentor-like programs up at the centers to help the young people not only get acquainted with the processes that go on at that center, but someone they can go to that will help guide them. That's going to help us, I think, but we're going to look very carefully at this last year's crop and the coming year's crop as to how well we can retain them.

Mr. GLICKMAN. What would a graduate student, let's say in aeronautical engineering, make starting out with no prior work experience, let's say a Ph.D. first?

Mr. BOYD. A Ph.D.?

Mr. GLICKMAN. Yes.

Mr. BOYD. In industry?

Mr. GLICKMAN. No, I mean for you.

Mr. BOYD. A Ph.D. is an 11, a GS–11. What does that equate to? About $27,000, $28,000.

Mr. GLICKMAN. And what would that person make, I wonder, going to work in the private sector?

Mr. BOYD. Well, I talked to some of them. I talked to the Ph.D.'s, the masters, and the BS folks, and if I can digress, the bachelor's degree people seem to be able to acquire anywhere from $3,000 to $4,000 more in industry than they do with us, so they make the judgment. They like the work, they like the facilities, they like the programs. I would say the Ph.D. people probably can make anywhere from $5,000 to $8,000 more working in industry than they can with NASA.

Mr. GLICKMAN. Yes, or obviously depending upon the economy.

Mr. BOYD. Sure.

Mr. GLICKMAN. But you feel much more optimistic and upbeat about the whole issue of the quality of the personnel, the retention, the morale, than perhaps 2, 3, 4 years ago?

Mr. BOYD. Well, I have been involved with NASA and NACA now for almost 38 years, and the last 2 or 3 years I see the most enthusiastic group of people coming out that I have seen in a long time. The main concern I do have is the retention rate. We still cannot move these young people along as fast as we would like to. We're doing pretty well. We hire some of the engineers in at what we call the advanced grade. That gives us some competitive edge, but once they get with us and stay for 2 or 3 years and get excited about the things they are doing—and we are trying to do that now intentionally—that could help us with the retention rate. We will not be able to compete with salaries. There is no way we can do that, so we have to use other devices. Educational opportunities, working with senior people who are expert in their field, the very unique facilities that each of our centers have, I think will help us.

Mr. GLICKMAN. Last year the committee expressed concern about the amount of time spent by NASA employees on administrative

matters. We asked you to examine alternatives for conducting NASA programs with a view towards increasing the number of aeronautical research personnel by 220. I wonder if you have done anything in this regard?

Mr. BOYD. Now you're asking me a question that comes out of the past. I know that in the past, between 1983 and 1984 we increased the number of people in aeronautics by a number like—Charlie, do you have it? We did increase the number of people in aeronautics, in a deliberate attempt to do some of that refocusing that you talked about. We're continually looking at what we can do in the administrative area, and one thing we hope to do——

Mr. TULIP. It's about 100 in 1984 from what it had been.

Mr. BOYD. We increased by about 100 from 1983 to 1984, but one thing we feel is going to be helpful to us, and we're getting our hands around it now, if we can really make the effective use of ADP and office automation that some people think we can—and Mr. Beggs is rather adamant about this—this, if we are going to invest in this area this should save people for us to put into the science and engineering areas.

Mr. NYSMITH. May I say a word?

Mr. BOYD. Bob has got the responsibility for that study. He might add to that.

Mr. NYSMITH. I would like to just say a word about that. I think in the letter we sent back to the Congress saying what we were doing, we did go out to the centers to conduct a survey and it was at all levels at the center, all the way down to the working level at the center, and it was a very broad survey. We didn't give them a form to fill out. We said, "What is it that is being done that you consider to be an impediment to you being able to spend your time doing R and D?"

We did collect those impediments and each and every one of them is now being addressed by a series of productivity councils within NASA. We intend later this year to collect those and the results and to actually quantify them to the extent that we're quite confident that we'll be able to show that when you add up the man-hours saved, that it will result in a fairly large number of hours now being devoted to R and D.

Mr. GLICKMAN. Could you share those results with the committee?

Mr. NYSMITH. Yes, we plan to do that.

Mr. GLICKMAN. OK. Well, I am going to yield my time now but I would just say that I think that you have presented a pretty good picture for us today. You know, this is one of the few Government agencies that still strikes a responsive chord with the American people. Even with the President asking for big sums in new ventures, I have not even felt that there is a semblance of great hostility back in my district, given the size of the budget deficits, which is an enormous challenge given where we are fiscally in this country. I expect you to do better than most other agencies——

Mr. BOYD. Yes, sir.

Mr. GLICKMAN [continuing]. You know, not that you're telling us something that—we have to do better, and from what you're telling me today I get the sense that you realize that as well.

Mr. BOYD. I think one interesting point, the people that we got this year—I made a list—they are from almost every State in the Union that we drew these people from, so they didn't just come focused around the centers, around which they may have grown up. The other point is that our co-op program, which you know much about, I'm sure, of the 600 we hired about 140 or 159[1] of them came from our co-op program, which is a really vital pipeline for this agency.

Mr. GLICKMAN. Thank you.

Mr. Volkmer?

Mr. VOLKMER. I would just like to thank you for your testimony, and I'm sorry I was here a little late.

Were there any items that you submitted to OMB or any increases that were cut back or anything, as far as OMB is concerned, that will cause you any difficulty?

Mr. BOYD. I don't think so. There were some small reductions in our baseline submittal, and small reductions in an augmentation that we have talked about and that survived the budget, the small reduction there, but I believe we are in reasonably good shape, Congressman.

Mr. VOLKMER. If your overall budget was, let's say, reduced by either this committee or the Appropriations Committee say $5 to $10 million, where would that basically be felt?

Mr. BOYD. I would like to submit that answer for the record but I would also like to make one observation, if I may. I suspect the main place that it would be felt would be in slowing down the rate at which we took some of the new people on board, or perhaps not taking as many on board. That would be one place. I imagine we would also back away a little bit on some of the supplies, materials, and equipments that we would normally—we would just delay them. That I believe is where we would do it.

[The information follows:]

FISCAL YEAR 1985 IMPACT OF REDUCTION TO THE R&PM APPROPRIATION

If the NASA R&PM request were reduced by $5.0 or $10.0 millions, the areas reduced would be chosen to minimize the impact on the support to the research, development and operation mission of the agency. The impact by impact area could be as follows:

1. In the area of Personnel and Related Costs we would have to curtail our training and temporary personnel programs, lengthen the interval between the time a person leaves and when the replacement arrives, and impact adversely our S&E fresh-out hiring program. The former action would be disruptive of carefully planned programs used to ensure the availability of future people and the upgrading of the skills of our current people to met the changing technical world. The latter actions would result in fewer FTE/FTP's to carry out approved programs, even though the end-of-year FY 1985 permanent employment may be at or about the level predicted in the FY 1985 Budget.

2. The number of trips our people will be able to take as part of the continuing NASA management review of our programs and contracts will be reduced. This will result in a less in-depth review of "what's going on" programmatically and administratively. We already have determined that the FY 1985 Travel plans should be at the currently planned FY 1984 level to assure that adequate surveillence of program and management activities is maintained, plus a small augmentation to allow for greater travel of our S&E's to scientific and technical meetings. The latter is especially important to assure our technical employees are current with work being

[1] The witness suggests that for accuracy this should read "about 100" instead of "about 140 or 159."

carried on elsewhere. A cut in the FY 1985 planned number of trips would be necessary to reduce costs if Research and Program Management is cut $5.0 or $10.0 million.

3. The number of support service contractor man-years we will be able to purchase would be reduced. This means that the support to the Research and Development program activities will be curtailed from and already austere level.

4. Purchases of supplies, materials and equipment planned for FY 1985 will have to be deferred into FY 1986. This will also impact the support to the Research and Development program, since we have not been purchasing these items at adequate levels in the past several years.

5. Make it very difficult to augment operational maintenance activities as planned in the Budget.

The specific degree that any of the above actions will be taken if the FY 1985 Research and Program Management request is reduced by $5.0 or $10.0 million is dependent on the actual FY 1984 pay raise supplemental appropriated, and the degree that actual price increases in FY 1985 may exceed the amount we estimated for them in the request.

Mr. VOLKMER. Any effect on travel or anything like that?

Mr. BOYD. We would try to make that as small as possible, and I'll say one word about that. I think that is a very important activity for us to continue, and the $800,000 that we did add is going to be critically important to get these young people out amongst their peers to talk about what they are doing and find out what other people are doing. That just makes a very modest increase in the amount. I think it makes one trip every 3 years additional for our scientists and engineers, so I would like to hold to that.

Mr. VOLKMER. And of course there is the necessity of movement between the centers and headquarters and the centers and the centers or the labs.

Mr. BOYD. And I think that is becoming more and more important with the new effort that we will have coming along in the space station.

Mr. VOLKMER. I have no further questions, Mr. Chairman.

Mr. GLICKMAN. Thank you.

Mr. Lujan?

Mr. LUJAN. Thank you, Mr. Chairman.

You're talking that it would slow down the rate of hires. The figures here show that for 1984 the total number of positions is 19,609 and for 1985, 19,634. That's 25 new hires. Are my figures incorrect?

Mr. BOYD. The civil service——

Mr. LUJAN. No, overall, including no change in executive level, no change in ES—executive service, is that it?

Mr. BOYD. Well, the civil service—you said 19,000? The civil service full-time equivalent number is 22,000 in 1984 and 1985. I'm not sure I recognize that number, sir.

Mr. TULIP. You have to go an extra page. You go to page SA-28 for the total.

Mr. LUJAN. You mean there's somebody lower than GS-2?

Mr. TULIP. Yes, sir. We have people who are wage board who are paid prevailing rates.

Mr. LUJAN. Oh, wage board. They're not GS.

Mr. TULIP. Those are not in the general schedule. They're in a different pay schedule.

Mr. LUJAN. That's where your new hires would be increased if there is going to be——

Mr. TULIP. No, it would be in the general schedule, but the number of end-year——

Mr. LUJAN. I don't understand the terminology, "general schedule" and all of that. I have here executive level, ES——

Mr. TULIP. Yes.

Mr. LUJAN. Senior executive service, is that basically what it is?

Mr. TULIP. Yes.

Mr. LUJAN. And then GS——

Mr. TULIP. Yes.

Mr. LUJAN [continuing]. And then you have the hourly wages.

Mr. TULIP. Yes.

Mr. LUJAN. OK. Excluding the hourly wages, it seems to be 25 additional positions.

Mr. TULIP. We will reduce the number of people at the end of fiscal 1985 who are paid prevailing rates by about 25, so that we increase the number of people paid on the general schedule by about that number.

Mr. LUJAN. So that it's going to be the same number, total number, the same total number?

Mr. TULIP. Approximately.

Mr. LUJAN. But you were saying that if the budget is cut, the new hires would be slower, but you don't intend any new hires.

Mr. BOYD. Well, no. May I say one word on that subject?

Mr. LUJAN. Yes.

Mr. BOYD. Each year we have an attrition of our people, of 1,200 to 1,400, people who retire, people who leave.

Mr. LUJAN. So you're saying you wouldn't replace them if——

Mr. BOYD. We wouldn't, we couldn't replace them as fast as we would like to, and therefore we might impact the rate at which we brought on the new people. See, we have a turnover that permits us to bring on additional people each year.

Mr. LUJAN. Yes, but when somebody retires at a GS–11, 12, 13, 14, you don't bring somebody in at the GS–11, 12, 13, or 14, so you have some additional funds there.

Mr. BOYD. You could have some savings with a GS–15 vis-a-vis a GS–9, and it is a staging process that we would probably have to reevaluate if we had less funds to cover it.

Mr. LUJAN. Well, that's right. The chairman points out that somebody is going to move in. If a 12 retires, an 11 is going to move up into it——

Mr. BOYD. Probably that, too.

Mr. LUJAN [continuing]. So you don't have the flexibility there.

At what level, degree level, is most of NASA?

Mr. BOYD. Well, we have about 15,000,[1] as I recall, scientists and engineers, and I'll get——

Mr. LUJAN. Oh, just a ballpark figure.

Mr. BOYD. I would say 20 or 30, 20 percent or so are Ph.D.'s, and another 30 percent, 30 to 40, are master's, and then the bachelor's, BS, thereabouts.[2] I can supply you that precisely——

Mr. LUJAN. Oh, no.

Mr. BOYD [continuing]. And that's from my experience at Ames, where I know the numbers pretty well.

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[1] This should be "about 11,000" according to the witness.

[2] According to the witness the actual figures as of the end of 1983 were 11.5% Ph.D.'s, 24% with master's degree and the balance with bachelor's degrees.

Mr. LUJAN. Does that ratio generally hold for new hires?

Mr. BOYD. No. As a matter of fact, the new hires now that we're talking about primarily come in at the GS–7 and GS–9 level, which means they're predominantly a bachelor's or master's degree. Then, of course, one of the appealing things in coming to us is, we permit them to continue their education, so a young fellow who comes in with a bachelor's might progress to a master's degree while working for us, but most of those are bachelor's and master's.

Mr. LUJAN. How long does it take, say, a GS–7 to move on up to an 11 or 12?

Mr. BOYD. Well, let's see. We can go from a 7 to a 9 in 6 months and a 9 to an 11 in 6 months—2 years, probably. From a 7 to an 11, 2 years would not be unusual.

Mr. LUJAN. Does that generally happen for somebody with a bachelor's or a master's?

Mr. BOYD. If they are above average, and most of ours are—I think the GPA of our hires, and in my talking to them I think they are above average, is like 3.2, the grade point average—so most of our people would move up right at that rate.

Mr. LUJAN. Would move up rather quickly.

Mr. BOYD. Yes, and that's very important, because if they didn't and they were good, they would leave for sure.

Mr. LUJAN. You have quite an effort in advancements for minorities and women.

Mr. BOYD. Yes, sir.

Mr. LUJAN. That's in your recruitment program or in your upgrading? Let me tell you what I'm getting at. A GS–11 and above is 71 percent of your work force, as I understand.

Mr. BOYD. That's correct.

Mr. LUJAN. Your overall minority and women is what? Seventeen percent? What is it overall?

Mr. BOYD. It is 15 to 17 percent. I think that's about right.

Mr. LUJAN. Seventeen percent, overall?

Mr. BOYD. Yes.

Mr. LUJAN. What about in that category of GS–11 and up?

Mr. BOYD. It's smaller, and I can't give you the exact number but it is smaller.

Mr. LUJAN. It is small, or more?

Mr. BOYD. It is a smaller percentage. We have been working very diligently for, I would say, since I have been involved in the EEO personnel activity, for 12 or 14 years to bring in people who we can get up into that category, females and minorities, and it has been a slow process.

Mr. LUJAN. When you say "smaller," are you talking about 1 percent, 2 percent, or 16 percent?

Mr. BOYD. In the 11 to 15 category I would estimate it is probably in the order of 6 to 8 percent, but again I would have to look at that. It is smaller than the overall. Of that I'm sure.

Mr. LUJAN. Is that moving?

Mr. BOYD. It's moving. It's moving slowly and, you know, as we move up into it and get additional minorities, we lose some at the other end, so we take two steps forward sometimes and maybe a half of one backward, but we are progressing. It's progressing and

it's a point that is very important to all of us, particularly in the high levels.

Mr. LUJAN. OK. Thank you.

Mr. GLICKMAN. Mr. McCandless?

Mr. MCCANDLESS. Thank you, Mr. Chairman.

Mr. Boyd, we have what some people refer to as zero-base budgeting, where they make—there are other terminologies but I will use that to try to explain it—where you do not assume that the activities you conducted in the previous year's budget are the base upon which to build the future budget that you're currently going to propose. In your budgeting process, how do you handle the fact of what went on in the previous year and whether or not you are satisfied with whether you got the biggest bang for the buck in the line items that totally make up the budget?

Mr. BOYD. I will start with a brief answer and turn that to Mr. Tulip, if you will, since he builds up our budgets.

I know in building them up at the centers we don't—we go through a fairly exhaustive process in terms of what we did last year, whether or not we want to continue doing that the coming year, and then what deltas we require to pursue the programs that we have. We do that over a period of several months at the centers, and the centers then input that to headquarters here.

If Charlie would like to comment on that, I would turn it over to him.

Mr. TULIP. Mr. McCandless, in the institutional area we have a number of people that are continuing on. We don't start, as you can imagine, with new people every year. What generally goes on in the institutional budget is that the center directors and the headquarters program managers decide what kinds of programs are going to be carried on, and that is done almost from a zero-base setup, depending on the degree to which the programs are short-term or long-term.

In the area of looking at the institutional budget, we try to make sure that we have a viable civil service work force, and that is one of the reasons the Administrator puts such emphasis on the hiring of recent graduates, to assure that our technical work force does remain vital. In the area of institutional support, we try to assure that the facilities and the support facilities that are used by those technical people are adequate.

It's a semi-zero-base budget, but when you've got a physical plant of $6 to $8 billion it really is—you just don't decide to startup a new technical facility in any given year and have it come on board that year, so that the level is a continuing level much more than it would be in the contracted work, but the real zero-base budgeting is done on how that is deployed during the year.

Mr. BOYD. I would say also, Congressman, that the centers—there are, while it's hard to believe sometimes, there are occasions and instances where we do shutdown things as we go through the study of what it is we need. We do put things either on standby, mothball, or just shut them down.

Mr. MCCANDLESS. Well, you've answered an aspect of it, which I appreciate. The other part of it was such things as services and supplies, capital expenditures, travel, those line items that make up the administrative overall budget of your agency——

Mr. TULIP. Yes.

Mr. MCCANDLESS [continuing]. Is there an evaluation as to—let's take the travel. You've emphasized the importance of travel. Is there an evaluation of the travel of last year and what it produced as a base point for deciding that you want to increase that travel? How do you arrive at the fact that X number of dollars—in this particular case I think you said $800,000 more—is going to be needed? Do you take what you had last year with satisfaction and say, "Yes, that is a good base point. We want to do more travel.—as you have explained, for the reasons you have explained—"therefore, that is going to cost $800,000. Therefore, that is going to be our proposed budget."

Mr. BOYD. Well, let me make one comment on that before Charlie does. We take the travel budget of the previous year in this case and that we concluded we had needed and used for the program reviews that we require, the contractual reviews that we require, and for going to scientific and technical meetings, we thought after an analysis was a very logical and needed thing to do. The programs are not decreasing; they are expanding.

In addition, as a result of the fact that we are getting the new people—we hope to get another 300 or so and in 1985 another group—we need to get these people out. We couldn't have accomplished that with the budget as it stood. That's where the $800,000 came up, which would permit us to get one person out every 3 years, sort of. It's a very modest attempt to get these people involved with their techncial groups.

Now you may want to take another statement on that, Charlie.

Mr. TULIP. Well, the travel is one of the areas where we look with each of the installations to see what their requirements are. In the area of the scientific and meeting travel it is a more clear-cut analysis. We had been concerned that we were not getting enough of our people out often enough to scientific and technical meetings. We had been able with the past budgets to do it about once every 3 years, an individual, and the $800,000 was developed as a basis to do it about once every other year. Now that doesn't mean that every scientist and engineer will go to a meeting every 24 months. That's just an average, but that was more easily done than some of the other traveling that the centers do.

We look at each center individually on what their travel plan has been, what they have used the money for, and come to an agreement on an approximate level. I can't give you a detailed analysis that says, "This is the formula by which we arrived there," but it is done in consultation with the centers to see that we have an adequate travel budget to do the programs that they are doing at the stage in which those programs are.

Mr. MCCANDLESS. Let me get into another area, with your permission, Mr. Chairman.

Mr. GLICKMAN. Fine. Both Mr. Volkmer and I have to leave at 12, so if possible I would like to limit. You go ahead and finish yours, and then from now on I want to limit the questions to like 10 minutes.

Mr. MCCANDLESS. Well, let me, just very briefly, another question: With respect to services and supplies such as the printing costs and so forth, have you done an analysis there to see whether

or not you are spending more in the current method by which you do this than if you were to, say, farm it out to the private sector?

Mr. BOYD. We are making one right at this moment to assure ourselves which way would be most advantageous for us to do, right now.

Mr. TULIP. Well, about 50 to 60 percent of our printing is now done commercially. We don't do it in our own printing plants. We are intentionally limiting the amount, and we have over the past several years, to that kind of printing that is difficult to get economically done on a quick turnaround basis in the commercial sector. We are working with the GPO and the OMB to see if there are further ways that we can contract innovatively with the printing industry to further reduce the overall cost of printing.

Mr. MCCANDLESS. Thank you. My reason for asking this question, I happened to be in one of the large governmental agencies the other day and they were xeroxing a form, rather extensively in numbers, which could have certainly been printed for far less in the numbers that they were doing it. You may say these are minor nuts and bolts things, but when you take the number of agencies, multiply it by the number of xerox machines, multiply it by the number of people that use those xerox machines, if you were to extrapolate that out to a final figure as far as the national level of Government is concerned, these things become very significant. That's why I took the time of the committee to ask some of these questions.

Mr. BOYD. Yes, sir. I appreciate that.

Mr. MCCANDLESS. Thank you, gentlemen.

Thank you, Mr. Chairman.

Mr. GLICKMAN. OK. Thank you.

We appreciate your testimony, Mr. Boyd.

Mr. BOYD. Thank you, Mr. Chairman.

Mr. GLICKMAN. Our last witness is Gen. Billie McGarvey, Director of the Facilities Engineering and Computer Management Division at NASA.

Good morning. In the interests of time, your entire statement will appear in the record so if you feel you can summarize—sometimes when we say "summarize" people spend longer than if they would read the statement, so however you think you can best accelerate the process, we would appreciate it.

Mr. MCCANDLESS. The key word is "accelerate". Is that right, Mr. Chairman?

Mr. GLICKMAN. Right. Ten to fifteen minutes.

General MCGARVEY. It's a very short statement.

Mr. GLICKMAN. You may want to read it, then.

General MCGARVEY. It's a 5-minute statement at the most.

Mr. GLICKMAN. Then read it. Don't summarize in 15.

STATEMENT OF BILLIE J. McGARVEY, DIRECTOR, FACILITIES ENGINEERING, NASA, ACCOMPANIED BY RICHARD IRWIN, DEPUTY DIRECTOR

General MCGARVEY. First I would like to introduce on my left, Richard Irwin, who is the Deputy for the Facilities Engineering Division.

Sir, we appreciate the opportunity to appear before you today to present the NASA construction of facilities budget request for 1985. Our request totals $160 million, a modest increase of $4.5 million above the amount that was appropriated in 1984, which included a one-time supplemental appropriation for space shuttle facilities. The 1985 request includes $98 million for major discreet projects; $50 million for minor projects; and $12 million for facility planning and design. The request is limited to priority facility needs with particular emphasis on exploiting the space shuttle's capabilities, enhancing key research facilities for aeronautics and space technology development, and improving our space communications capabilities.

Without going into great detail, I would like to discuss some of the major construction projects included in the request. There are several projects which will significantly aid NASA in exploiting the demonstrated capabilities and achievements of the shuttle.

At the Kennedy Space Center we propose to construct additions to the cargo hazardous servicing facility. As we projected in last year's budget request which provided the basic servicing facility, this year we have a firm requirement to construct an environmentally controlled airlock and a separate payload control building. The principal thrust behind this project is to increase the payload processing throughput from four payloads per year to eight. With the airlock, stringent contamination control integrity of the servicing bay can be maintained during entry and exit of payloads, transporters, and related ground support equipment. Likewise, by providing a payload control building the processing rate will not be hampered by the time-consuming setup and dismantling of monitoring equipment in the cells or the flight monitoring of previously processed large hazardous cargoes.

The construction of a biomedical research facility at the Ames Research Center for $2.1 million will replace a makeshift collection of aging and inadequate trailers used for laboratories and support facilities associated with the animal care facility. Ames is NASA's lead center for aerospace animal research, and this project will provide an improved research environment, better quality of veterinary care, and the concentration of all animal research in a single-building complex, and is needed now to adequately support flight rates and research program priorities.

Another significant item in the request that we wish to highlight is the second increment of funds that is required to complete construction of two key facilities at the Kennedy Space Center. Initial funding in the amount of $20 million was included in the 1984 general supplemental to construct a solid rocket booster assembly and refurbishment facility and a launch complex 39 logistics facility. The 1984 column of our summary pages in the budget book for 1985 reflects this change to the 1984 program. You may recall that we had originally planned to provide these facilities via contractor investments that would be amortized through production and operation contracts. Consultation with the Appropriations Committees subsequently determined that up-front Government funding was the preferred course of action. Construction funds were provided for the first phase of construction in the supplemental appropriation, with an understanding that the balance of the funds required

to complete the facilities would be provided in fiscal year 1985; $15 million for the SRB facility and $10 million for the logistics facility has been included for this purpose. Both of these projects are currently under design and will go to construction in the mid-1984 timeframe.

Among the discreet construction projects that will provide significant enhancement of NASA's aeronautics and space technology capabilities are three that I would like to touch on. The first project at Ames is a $16.5 million facility to house the numerical aerodynamic simulation activities that are being developed to provide advanced high-speed computational capability for aerodynamic research, aeroelastic simulation, and fluid physics research. The NAS activities will provide and maintain a leading computational capability for NASA, other Government agencies, industry, and universities in this country. This facility will house the NAS processing system network of state-of-the-art computer systems, associated peripheral equipment and hardware, and the researchers and the development staff.

The second large project in this category is modifications to Langley's 8-foot-high temperature tunnel. These modifications are estimated to cost $13.8 million and will provide aerothermodynamic and structural testing capability for air-breathing propulsion systems for aircraft and missiles which operate at altitudes from 50,000 to 120,000 feet and between speeds of Mach 4 and 5. Research capability for testing hydrogen and hydrocarbon fueled ramjets and scramjets will also be provided by these facility mods.

In the space science and applications category, a third project is a request for $12.2 million to construct an Earth and space science laboratory at the jet propulsion lab in California. This facility is needed to house the laboratory equipment and activities of approximately 295 scientific, engineering, and related personnel who are working on expanding radar, oceanography, and electronic component development and test programs. Radar and oceanography activities being conducted at the JPL include the shuttle imaging radar, the Venus radar mapper, the ocean data archives system, and other programs in the early development stages. In addition, spacecraft design requirements have been causing an increasing demand for the test and integration of microelectronic systems using large-scale, very large-scale and very high-speed integrated circuits. The application of these complex and unique microelectronic components in spacecraft systems requires testing and evaluation which exceed the present capabilities of JPL, our other NASA centers, and industry.

These spacecraft development activities are presently inadequately housed in a number of dispersed buildings and trailers which are overcrowded and cannot be economically expanded or modified to accommodate the necessary test and data analysis equipment. This new laboratory will eliminate these deficiencies and facilitate improved information exchange among the radar, oceanographic, and electronic component development personnel, and reduce duplication of facilities and administrative costs.

Also in this year's request are two projects that significantly extend and improve the tracking and data acquisition capabilities of the NASA deep space network. Both projects are located at the

Madrid, Spain deep space network complex. One project provides for the construction of a new 34-meter antenna similar to previous years' projects at the Goldstone site and at the Canberra, Australia deep space network site. The other project is the modification of a 64-meter antenna by expanding the dish diameter to 70 meters, and is the first of three projects that we are considering for each of the 64-meter antennas.

The new 34-meter antenna in Spain will help provide support for the Voyager 2/Neptune encounter in 1989 and the required increase in aperture at the Madrid complex for this mission will be provided by this 34-meter antenna and by the previously mentioned modifications to the 64 meter. These two will be arrayed with an existing 34-meter antenna to provide sufficient aperture for receiving Neptune images at the Madrid location. It's also required to support the Galileo mission with gravity wave experiments in late 1987 and late 1988, and for critical backup for very long baseline interferometry navigation for the Galileo probes beginning in March 1988.

As previously mentioned, we also are requesting $7.8 million for the modification of the 64-meter antenna. This is needed in support of the same missions and is needed for improved communication capability for deep space missions. Its upgrading is necessary to support, as I said earlier, Galileo, Venus radar mapper, and Voyager/Neptune missions.

Before closing, I would like again, as in prior years, to request your full support of the level of funding that we are requesting for our minor programs. The repair, rehab, and modification projects and minor construction projects that make up the minor program continue to be the backbone of NASA's facility support activities. These projects, with strong support by you, have enabled us to address many of our most pressing and widespread facility needs.

With facilities the age of ours, extensive repairs are needed every year to continue to protect the Government's investment in unique and valuable aerospace facilities. Likewise, technical advances and breakthroughs have been achieved and will continue to be achieved in the future with necessary facility support that is provided in large part by rehabilitation and modification of existing facilities. This category of work has been instrumental in enabling NASA to retailor our laboratories and test facilities to undertake new tasks and exploit the latest technological developments. To continue and enhance the usefulness of the minor program budget categories, we are requesting an increase in the funding limits for these individual projects. We have operated under the current limits for over 10 years now, and the deep erosion in facility project buying power over this period dictates the necessity for raising the funding limits. We are requesting the past limit of $500,000 for repair projects and rehabilitation and modification projects be increased to $750,000, and the $250,000 limit for minor construction be raised to $500,000.

Finally, I would like to thank you again, Mr. Chairman, for both committees' solid support of the NASA CoF budget request in the past and the vital programs that it supports.

This completes the statement, and I will be happy to address any question you have.

[The prepared statement of General McGarvey:]

HOLD FOR RELEASE UNTIL
PRESENTED BY WITNESS
March 1, 1984

STATEMENT
OF

BILLIE J. MCGARVEY
DIRECTOR OF FACILITIES ENGINEERING

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS, AND
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

Messrs. Chairmen and Members of the Subcommittees:

I appreciate the opportunity to appear before you today to present the NASA Construction of Facilities budget request for FY 1985. Our request totals $160 million, a modest increase of $4.5 million above the amount appropriated in 1984 which included a one-time supplemental appropriation for Space Shuttle facilities. The 1985 request includes $98 million for major discrete facility projects, $50 million for minor projects, and $12 million for planning and design. The request is limited to priority facility needs with particular emphasis on exploiting the Space Shuttle's capabilities, enhancing key research facilities for aeronautics and space technology development, and improving our space communications capabilities.

MAJOR FACILITY PROJECTS

Without going into great detail I would like to discuss some of the major construction projects included in this budget request. There are several projects that will significantly aid NASA in exploiting the demonstrated capabilities and achievements of the Space Shuttle.

SPACE SHUTTLE AND PAYLOADS

At the Kennedy Space Center, we propose to construct additions to the Cargo Hazardous Servicing Facility. As we projected in last year's CoF budget request which provided the basic servicing facility, this year we have a firm requirement to construct an environmentally controlled airlock and a separate payload control building. The principal thrust behind this $4.6 million proposed project is to increase the payload processing throughput from four payloads to eight payloads per year. With the airlock, stringent contamination control integrity of the servicing bay can be maintained during the entry and exit of payloads, transporters and related ground support equipment. Likewise, by providing a payload control building, the processing rate will not be

hampered by time consuming set-up and dismantling of monitoring equipment in the cell nor the flight monitoring of previously processed large hazardous cargoes.

The construction of a Biomedical Research Facility at the Ames Research Center for $2.1 million will replace a makeshift collection of aging and inadequate trailers used for laboratories and support facilities associated with the Animal Care Facility. Ames is NASA's lead center for all aerospace animal research. This project will provide an improved research environment, better quality of veterinary care, the concentration of all animal research in a single building complex, and is needed now to adequately support flight and research program priorities. NASA considers this to be an important and priority requirement.

Another significant item in this request that I wish to highlight is the second increment of funds that is required to complete construction of two key facilities at the Kennedy Space Center. Initial funding in the amount of $20 million was included in the FY 1984 General Supplemental to construct a Solid Rocket Booster Assembly and Refurbishment Facility and an LC-39 Logistics Facility. The FY 1984 column of the summary pages in our FY 1985 CoF budget request reflects this change. You may recall that we had originally planned to provide these two facilities via contractor investments that would be amortized through the production and operations contracts. Consultation with the Appropriations Committees subsequently determined that up-front government funding was a preferred course of action. Construction funds were provided for the first phase of construction in the supplemental appropriation with an understanding that the balance of funds required to complete the facilities would be provided in FY 1985. $15 million for the SRB facility and $10 million for the logistics facility have been included for this purpose. Both projects are currently proceeding in the design and acquisition process with construction planned to get underway in mid-1984.

AERONAUTICS AND SPACE TECHNOLOGY

Among the discrete construction projects in our CoF budget request that will provide significant enhancement of NASA's aeronautics and space technology capabilities are three that I would like to highlight. The first project at the Ames Research Center is a $16.5 million facility to house the Numerical Aerodynamic Simulation (NAS) activities that are being developed to provide advanced highspeed computational capability for aerodynamic research, aeroelastic simulation, and fluid physics research. The NAS activities will provide and maintain a leading computational capability for NASA, other governmental agencies, industry, and universities. This facility will house the NAS processing system network of state-of-the-art computer systems, associated peripheral equipment and hardware, and the researchers and development staff.

The second large project in this category is the proposed modifications to the Langley Research Center's 8-Foot High Temperature Tunnel. These modifications are estimated to cost $13.8 million and will provide aerothermodynamic and structural testing capability for air-breathing propulsion systems for aircraft and missiles which operate at altitudes

from 50,000 feet to 120,000 feet and at speeds between Mach 4 and 5. Research capability for testing hydrogen and hydrocarbon fueled ramjets and scramjets will also be provided by these facility modifications. Primarily, this project will provide a full-scale test capability in the Mach 4-5 range with provision for accurately simulating atmospheric oxygen conditions at altitude.

SPACE SCIENCE AND APPLICATIONS

The third project is a request for $12.2 million to construct an Earth and Space Science Laboratory at the Jet Propulsion Laboratory. This facility is needed to house the laboratory equipment and activities of 295 scientific, engineering and related personnel who are working on rapidly expanding radar, oceanography, and electronic component development and test programs. Radar and oceanography activities being conducted at JPL include the Shuttle Imaging Radar, the Venus Radar Mapper, Ocean Data Archives and other programs in the early development stages. In addition, spacecraft design requirements have been causing an increasing demand for the test and integration of micro-electronic systems using large scale, very large scale,and very high speed integrated circuits. The application of these complex and unique electronic components in spacecraft systems requires testing and evaluation which exceed the present capabilities of JPL, other NASA centers, and industry. These spacecraft development activities are presently inadequately housed in a number of dispersed buildings and trailers which are over-crowded, cannot be economically expanded to accommodate the necessary test and data analysis equipment, and cannot be modified for needed clean-room environment and temperature and humidity control. This new laboratory facility will eliminate these deficiencies and facilitate improved information exchange among the radar, oceans and electronic component development personnel, and reduce duplication of facilities and administrative costs.

SPACE TRACKING AND DATA SYSTEMS

In this year's CoF budget request there are also two projects that will significantly extend and improve the tracking and data acquisition capabilities of the NASA Deep Space Network. Both projects are located at the Madrid, Spain DSN complex. One project provides for the Construction of a new 34-Meter Antenna similar to previous years' projects at our Goldstone, California and Canberra, Australia DSN sites. The other project, Modification of the 64-Meter Antenna by expanding the dish diameter to 70 meters, is the first of three similar projects that we are considering for each of our 64-meter antennas.

The construction of a new 34-meter antenna in Spain will help provide support for the Voyager 2 - Neptune encounter in 1989. The required increase in aperture at the Madrid complex for this mission will be provided by this 34-meter antenna, and by the previously mentioned modifications to the 64-meter antenna. These two antennas will be arrayed with an existing 34-meter antenna to provide sufficient aperture for receiving Neptune images at the Madrid location. It is also required to support the Galileo mission with gravity wave experiments in late 1987 and late 1988, and for critical back-up of very long baseline interferometry navigation for the Galileo probe beginning in March 1988. This $6 million antenna is also needed for improving multiple

mission support capability to meet communications requirements in the late 1980's and beyond. These include not only the Voyager 1 and 2 and Galileo missions, but also such missions as the Venus Radar Mapper, Pioneer 10, Pioneer 11, Pioneer Venus Orbiter, and the International Solar Polar Mission.

As previously mentioned, we are also requesting $7.8 million for Modifications to the Madrid 64-Meter Antenna to increase its diameter to 70 meters. This is needed for improved communication capability required for deep space missions. The upgrading is necessary to support Galileo, the Venus Radar Mapper, and the Voyager 2 - Neptune missions and continuing support to spacecraft beyond the outer planets.

MINOR FACILITY PROJECTS

Before closing, I would like to again, as in past years, request your full support of the level of funding we are requesting for our minor programs. The Repair, Rehabilitation and Modification, and Minor Construction projects that make up the minor programs continue to be the backbone of NASA's facility support activities. These projects, with strong support by you, have enabled us to address many of our most pressing and wide-spread facility problems. With facilities the age of ours, extensive repairs are needed every year to continue to protect the government's investment in unique and valuable aerospace R&D facilities. Likewise, technology advances and breakthroughs have been achieved and will continue to be achieved in the future with the necessary facility support that is provided in large part by rehabilitation and modification of existing facilities. This category of work has been instrumental in enabling NASA to re-tailor our laboratories and test facilities to undertake new tasks and exploit the latest technological developments. These projects not only help preserve and enhance the capabilities and usefulness of our facilities, but also help insure their continued safe and economical use. Similarly, the minor construction projects provide the opportunity to build limited but essential additions or new facilities that are critically needed.

To continue and enhance the usefulness of the minor CoF program budget categories, we are requesting an increase in the funding limits for individual projects. We have operated under the current limits for over ten years now, and the deep erosion in facility project buying power over this period dictates the necessity for raising the funding limits. We are requesting that the past limit of $500,000, for repair projects and rehabilitation and modification projects be increased to $750,000; and that the $250,000 limit for minor construction projects be raised to $500,000. As stated earlier, we rely heavily on these minor projects to repair and restore our facilities, make limited modifications for changes in activities and R&D advances, and to provide limited additions to meet new or expanding requirements. These requested increases in the current project funding limits will permit us to accommodate priority facility needs in a more flexible and timely manner.

Summary

Finally, I would like to thank you again for your solid support of the NASA CoF budget request and the vital facility program that it supports. This completes my prepared statement and I will be pleased to address any questions you may have.

Mr. GLICKMAN. Thank you, General McGarvey.

Most of the questions are in Mr. Volkmer's subcommittee because they relate to facilities there. I don't know if he is going to have very many, but I would just ask you one question in connection with the construction of the numercal aerodynamic simulation facility: What would be the impact of deferring this project for 1 year on the simulation activities at Ames, that is, the actual building of the facility?

Mr. MCGARVEY. Sir, it would have a severe impact on the overall development program, the numerical aeronautical simulation program itself, primarily because we are operating in an existing central computer facility by crowding the current activities into the same building with ongoing central computer activities and there simply isn't enough physical space in the one building to accommodate both activities. There is space that has been made available to carry it through the initial operating configuration phase, but there certainly is not nearly enough space to carry it through its extended configuration phase and its full capabilities.

If you ask what's the specific impact on the program itself, for example, we could not buy the second high-speed processor, which is a very key element to achieving the full capability, simply because there would be no place for us to house that computer and the peripheral hardware that goes with it. This in turn means that without the second high-speed processor and the other hardware, that you have a loss in speed capability that you are trying to develop from the 250 million floating operations per second that are provided by the first high-speed processor, versus 1,000 million floating operations per second, or a 4-to-1 loss in speed capability.

The same thing holds true in central memory capability. It's a reduction of 4 to 1 which would be delayed for the time that you deferred it, and in the mass storage capability it's even greater. It's an 8 to 1 loss in the capability for mass storage if we do not have the space in order to accommodate the second phase of this development effort.

Mr. GLICKMAN. Let me ask you this question: Why has 26,000 square feet of space been set aside for office space, in connection I guess with the NAS facility. Presumably this is not for engineers, who would maintain their present offices. I'm just wondering if it's going to require over 200 people to operate these computers.

Mr. MCGARVEY. Well, you are correct, sir, that it doesn't require 200 people to operate them, but we are providing space in that facility for the researchers and the developers, the aeronautical researchers who are doing the scientific research themselves, space in the same facility, as well as I think you recognize that this is a continuing evolutionary development of the NASs, and there are other research and development folks who will continue to expand it and enhance its capabilities who are also located in that facility. In addition there are the operational support people and the facility maintenance people that are in the building itself.

Mr. GLICKMAN. Going back to my first question about deferring the construction of the project, if you had to calculate now as to if we delayed the construction of the facility for 1 year, does it delay the NAS plan for 1 year? I mean, does it delay the whole project?

Obviously we're going to be doing some additional work on it during the interim.

Mr. McGARVEY. That's right. If you were to take a look at the detailed master schedule for the overall program development, of which the facility is a key element of that overall program, it's interlocked into the schedule and it is on the critical path, so that it is a key element in the timing and becomes one of the controlling milestones for reaching the full development of the NASs capability.

If you defer it for a year, you are certainly going to defer the whole development at least a year because there simply isn't space to accommodate it at Ames.

Mr. GLICKMAN. OK. Thank you.

Mr. Volkmer?

Mr. VOLKMER. Yes; I just have a couple of questions. One of them, I notice in here on the solid rocket booster assembly and refurbishment facility your statement that the construction is planned to get underway in mid-1984. Does that mean April or May or——

Mr. McGARVEY. Yes, sir. Mr. Volkmer, it's tied, the facility is tied to a request for proposal for the recompetition of the procurement of the solid rocket boosters themselves, the total buy including refurbishment of these components, and one element in the request for proposal is that each proposer submit his proposed design of the processing facility, the manufacturing facility, for doing those refurbishment activities.

Those RFP's, the proposals are due back in in mid-March, this month, and with them will come the proposed designs at the 60-percent stage of a final design, which would permit us then, after the selection is made for that contract, to immediately start the construction of the facility for the successful offeror. That is why we said the mid-1984 timeframe. I don't have the specifics. It's a selection evaluation board process for selecting the successful contractor, and whether that is going to take 60 days or 90 days I'm not sure.

Mr. VOLKMER. Well, we're really looking, before you're going to break ground, we're really looking until summer then, are we not? July?

Mr. McGARVEY. Except you may recall we came to you previously, notified the committees with a request for reprograming for about $3.5 million for a site preparation package for this facility, which we have bids in hand at the moment for that site preparation package. Those bids are being evaluated and we will put that under construction in the very near future. That prepares the site, brings the long-line utilities, the power, the gaseous nitrogen and the other facilities to the site for the successful contractor then to build the facility on that site.

Mr. VOLKMER. Well, you understand the problem that we're faced with as far as having this facility completed in time enough to accommodate the flight rate for the shuttle by 1986, 1987, 1988 timeframe. When do you have completion of the refurbishment facility scheduled?

Mr. McGARVEY. The schedule that we are working against is to initiate the actual construction of the facility itself, granted we are

starting earlier than this with site preparation, but initiate the construction of the facility in August of this year, August 1984, as a 21-month construction period, which means it will be completed in April 1986. As you know, the target of flying 24 flights per year, of which 18 of them would be out of KSC, is in the 1988–89 timeframe, so it will come on-line in time to support that. One of the targets is to transition from the present facility into this facility at about flight set number 39, or for about the 39th flight, and that is in the late-1986 timeframe.

Mr. VOLKMER. So in late 1986 you will be using the facility for refurbishment for future flights?

Mr. MCGARVEY. Yes, sir. It has about, as I recall, about a 6-month activation period after the completion of construction, and then we would phase it——

Mr. VOLKMER. Getting all the tooling and all the equipment and everything else?

Mr. MCGARVEY. That's right.

Mr. VOLKMER. All right. Now in the building for the logistics facility, are there any plans to include any office space in this building?

Mr. MCGARVEY. There is a small area of office space in the building for the logistics operations themselves, for the people that do that. It's not very large, a very small office area, but the bulk of the program is devoted to storage and support of spares and supplies at the launch complex in support of the launch processing contractor.

Mr. VOLKMER. Then the personnel are going to continue to be housed in trailers?

Mr. MCGARVEY. Some of them will. As you know, we have a large trailer complex there now of well over 200 trailers in the vicinity of LC–39, which is a temporary expedient. It leads to the question, I'm sure, "When are you going to replace those?" Two things really impact as to when we can do that. One is the budget constraints, as to when we can fit in permanent replacements. The other one, we do not feel comfortable at this point, until we get more operational experience under our belt, as to what the exact need is going to be in total numbers of people. We would hope that one of the objectives is to reduce that number and see the requirement come down as opposed to seeing it increase.

Mr. VOLKMER. Well, if the total logistics facility for parts, et cetera, for the shuttle is, let's say, moved to Kennedy, that would be just the opposite effect, would it not?

Mr. MCGARVEY. I didn't understand your question, sir. Did you say the total——

Mr. VOLKMER. If the total logistics program for the parts, et cetera, moved to Kennedy.

Mr. MCGARVEY. Well, everything is there now as far as spares and support requirements, is at KSC now with the exception of the thermal protection tiles which are still located at the Palmdale plant, and then of course structural spares for the Orbiter vehicle itself which would require a manufacturing facility if you——

Mr. VOLKMER. Well, there are some personnel, as I understand it, for logistics that are presently in Johnson also. I may be wrong on that. That's my understanding. Maybe I'm wrong, but either way

what I'm getting at is, when can we see these people permanently housed?

Mr. McGARVEY. Well, again I would say that the two primary factors will be when we can fit it into a budget. You know, it's a very large requirement. We have about 1,800 people housed in trailers now at KSC, and it was a candidate project this year for a permanent office facility to replace a portion of those, and it simply didn't compete with other programmatic requirements when we had a temporary expedient that was handling it for the moment. I'm sure that in future budgets we'll have the same kind of requirement.

Mr. VOLKMER. Any possibility in design, or probably design for the logistics facility is already completed. Is the design already completed?

Mr. McGARVEY. No, sir, it's not completed.

Mr. VOLKMER. Any possibility in designing that, to design it in such a way that it can be expanded to include office space?

Mr. McGARVEY. There is that possibility and we'd be happy to look at that, but the present plans, it's expandable primarily for the logistics and not for office space.

Mr. VOLKMER. Right. I have no further questions.

Mr. GLICKMAN. Thank you.

Mr. McCandless?

Mr. McCANDLESS. Thank you, Mr. Chairman.

Prior to leaving, Mr. Lujan asked me if I would bring up an area that he had some concern about relative to page 2 in your discussion, which would probably piggyback on what has been said, the solid rocket booster assembly and refurbishing facility and an LC-39 logistics facility, and then he talked here about the up-front Government funding was a preferred course of action. Then he used a facility in the South owned by Martin-Marietta, if I understood him, that is leased. If I caught the train of his desire for questioning, it dealt with the fact that this leased facility either would be available and could be purchased or leased to the Government, or that he was wondering if the leased facility might not have a better potential than a funded facility. Am I making sense to you when I insert the Martin-Marietta aspect of it?

Mr. McGARVEY. I am a little confused by it——

Mr. McCANDLESS. Well, the problem he had was that when you have a prime contractor and they own the facility, the Government does not have the flexibility of going into negotiations with another contractor without also including either the purchase of facilities for that contractor or the leasing of facilities or the cost of the facilities being included in the prime contract. I must confess that the short, once across lightly he gave me, I don't have the background that he does to be able to draw upon, in his committee and his history with the full committee. Are we talking here about leased facilities versus purchased facilities, and the leased facilities might have more advantage or the purchased facilities might have more advantage?

Mr. McGARVEY. No, sir. We were talking primarily of, and I guess you could term it "leased" but in effect it would be a purchased facility, and we were talking about the options of having the contractor, if it were Martin-Marietta—in this case it is Lock-

heed, in the case of the logistics building—of having the contractor provide the building and the building amortized then during the course of his production contract or his operations contract, and at the given point in time where it was amortized the Government—title would pass to the Government and it would become a Government-owned facility at that point.

The Appropriations Committees took exception to doing that and said, "We would prefer that the Government fund the project and it be funded up front," and that prompted them to add it to the supplemental bill in 1984. The Martin-Marietta thing, I appeared confused because Martin-Marietta, their major contract with NASA is at the assembly facility in New Orleans where we build the external tank. That is a Government-owned facility, a Government-owned plant, contractor-operated, so it's a GOCO plant, and I am not aware of any leased facilities that we utilize by the Martin-Marietta people.

Mr. McCANDLESS. I think, now that you have expanded on that, what he was interested in was the ability of the Federal Government to control the physical facilities: In the event that the prime contractor did not function according to schedule or contract, that the Federal Government would have the ability then, by owning the facilities, to find another prime contractor, rather than what I understand now to be a situation where, until such time as the contract has been completed, the Government does not have title to the facilities.

Mr. McGARVEY. That's right, but in the contractual arrangements, when we were considering these as contractor investments, there were proposed provisions that if the contract were to be terminated for any reason--whether it was the termination of the program or if it was inadequate performance on the part of the contractor—there were provisions in it for termination liabilities to pay off the remainder of the unamortized investment of the contractor and the Government to take over the facility or to pass it to another contractor. It had that kind of legal provision in it, which we believed was workable.

Mr. McCANDLESS. I believe that is the area in which he wished me to discuss.

I have one quick question, if I may, Mr. Chairman.

Mr. GLICKMAN. Sure.

Mr. McCANDLESS. With respect to these kinds of negotiated instruments, in the case of the one in question, when you take the actual Government ownership from day one and the contractor moves in, and you take one of these amortized type contracts such as we are talking about here, has an analysis been made as to the percentile differential in the total use of that building during the contract time, and has there been any analysis as to the cost percentagewise to the total contract for the amortization aspect of it?

Mr. McGARVEY. Yes, sir. Those were done previously on cost-benefit analyses across the board, comparing contractor investment and amortization of his cost and a reasonable return on his investment vis-a-vis the Government providing the facilities. Our determinations earlier were that it was cost-effective for us to do that through contractor investments, but we were not successful in proceeding with them on that basis.

Mr. MCCANDLESS. I guess the reason I asked the question would be, if I am going to build a building and borrow the money to do so, I am going to have to go out on the open market. The Federal Government borrows the money and builds the building, and the rate of interest that it pays is going to be less than the contractor, and therefore it would appear on the surface, anyhow, that this would reflect a favorable overall cost to the Government if it were to do the actual construction or make arrangements for the construction. That's why I asked the question.

Mr. MCGARVEY. Yes, sir, and in some instances when you look at the total analysis, if you look at the other side of lost revenue, if the Government borrows the money at a given rate and builds the facility, and you look at the lost tax revenue then that they would accrue from the contractor owning the facility, in some instances it is more cost-effective to have the contractor do that. We have examined a number of those in the last couple of years.

Mr. MCCANDLESS. Thank you.

Thank you, Mr. Chairman.

Mr. GLICKMAN. Thank you, Mr. McCandless.

We have no further questions. We appreciate your testimony today very much.

Mr. MCGARVEY. Thank you, sir.

Mr. GLICKMAN. The hearing stands adjourned.

[Whereupon, at 11:45 a.m., the subcommittees recessed, to reconvene at the call of the Chair.]

APPENDIX 1

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of C:MDD:C-12229f

FEB 8 1984

Honorable Harold L. Volkmer
Chairman
Subcommittee on Space Science
and Applications
Committee on Science
and Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed are our responses to your written questions on NASA's FY 1985 Research and Development funds which were forwarded by your December 19, 1983, letter.

We are looking forward to working with you and your staff during this session of Congress and appreciate the support which you have given to our programs.

Sincerely,

John F. Murphy
Assistant Administrator
for Legislative Affairs

Enclosure

Responses to written questions from Chairman Volkmer

QUESTION 1:

Please furnish the following tabulation, by major programs, for the FY 1985 budget request:

a. the original recommended budget to OMB,
b. the adjustments made,
c. the submission to Congress,
d. brief comment on the adjustments made, if any,
e. the comparative FY 1984 operating plan figure,
f. please assign an agency priority to those programs requested from OMB but not presented to Congress

ANSWER:

See Table A

QUESTION 2:

Please furnish the following information, by NASA Center and by major program, for the FY 1985 budget request:

a. original Center request to NASA Headquarters,
b. the adjustments made,
c. brief comments on adjustments made,
d. the submission to Congress as allocated by Center, and
e. the comparative FY 1984 operating plan figure, by Center

ANSWER:

See Table B

QUESTION 3:

Please furnish by major line item, the NASA operating plan for FY 1983 and FY 1984 with comments on adjustments, if any.

ANSWER:

See Table C

QUESTION 4:

Please provide a tabulation of projected total costs of all major programs including: (please include initial estimates for budgeted new starts)

a. original estimate date and amount,
b. current estimate, and
c. NASA's estimate of what portion of any increased cost may be due to inflation

ANSWER:

See Table D

QUESTION 5:

Please provide an analysis of the effect of inflation on the aggregate buying power of NASA. Please include a separate summary of the Space Shuttle program cost estimates and the effect of inflation on total cost at completion estimates.

ANSWER:

See Tables E and F

QUESTION 6:

Please furnish, by major program, the unobligated balance of funds for FY 1983 and FY 1984 and the actual or estimated carry over as of January 15, 1984.

ANSWER:

See Table G

QUESTION 7:

Please provide a summary of the Space Shuttle production sub-line item by major program elements and by production orbiter vehicle including initial cost estimates, current cost estimates, all changes which have occurred, and associated schedule changes.

ANSWER:

At the time of the Shuttle development commitment, the requirements to establish an operational orbiter fleet were projected at $1 billion in 1971 dollars. This estimate was to provide for the modification or refurbishment of two orbiters (Orbiter 101 and 102) bought in the development phase and the procurement of three additional orbiters.

Since that original estimate, planning for the implementation of the orbiter fleet has been impacted by budget reductions, orbiter delivery schedule adjustments, revised estimates based on experience in the development phase, and new requirements identified during the development test flight program. These include the FY 1977 budget decision to defer the start of production; schedule adjustments related to the Agency's realignment of program funding between design, development, test and evaluation and Production in FY 1978 and FY 1979; the FY 1979 budget decision to delay proceeding with a fifth orbiter; the actual orbiter and main engine fabrication and assembly experience on development hardware; the delivery schedule stretchout included in the FY 1980 and FY 1981 budget plans; and the identification of new requirements, such as the orbiter weight reduction program and systems engineering support. Based on the combined effects of these varied impacts, the current estimate to establish the fleet of operational orbiters is $3.595 billion in dollars of the FY 1985 budget which is equivalent to $1.719 billion in FY 1971 dollars. This estimate provided for modifying Orbiter 102 in FY 1983 after its use for the orbital flight test program and early operational flights in order to support the first Spacelab mission, and includes subsequent structural modification in FY 1985

to support full operational use, upgrading the orbiter structural test article to an orbital configuration (Orbiter 099), and the fabrication and assembly of two additional orbiters and associated main engines. Three production vehicles have now been delivered and the fourth orbiter is starting in final assembly.

A comparison of the original and current production orbiter delivery schedules is a follows:

	Orbiter Deliveries	
	Original Plan (03/72)	Current Plan
Orbiter 101 Modified	March 1979	--
Orbiter 099 (STA Modified)	--	July 1982 (Actual)
Orbiter 102 (Spacelab Mod)	--	July 1983 (Actual)
Orbiter 103	December 1978	October 1983 (Actual)
Orbiter 104	October 1979	December 1984
Orbiter 105	August 1980	--
Orbiter 102 Full Mod	December 1980	FY 1985

In addition to fleet investment, the current Shuttle Production and Capability Development budget planning also includes orbiter and second-line facility ground support equipment at KSC required for a capability to process more than one vehicle concurrently; system integration and support activities; the procurement of an initial inventory of operational spares and crew equipment; the procurement of SRB and and ET rate tooling to meet the projected 24 per year flight rate capability; the provision for modifications to incorporate Centaur within the Shuttle vehicle, the development of a Filament Wound Case for the Solid Rocket Booster to Augment Performance and Changes and Systems Upgrade to provide for potential changes or systems modifications required from flight experience or to increase reliability and safety and to lower STS operating costs.

QUESTION 8:

Please provide a requirements and production cost analysis for a Fifth Orbiter based on initiating the production buy in Fiscal Year 1985 compared with Fiscal Year 1986 and Fiscal Year 1987 including the implication of the loss of an orbiter, the implications of an orbiter being out of service for an extended period, and the implications regarding maintenance of the subcontractor base.

ANSWER:

The need for a fifth orbiter has been studied over the past several years, including an intensive review for the FY 1984 budget submittal to Congress. These studies, conducted by both internal and external groups, have reached the same basic conclusion that the currently authorized four orbiter fleet can support the projected launch requirements through the end of this decade.

A complete review of the sensitivities and cost as related to an enlarged STS Orbiter fleet has been provided to Congress on February 1, 1984. The capability to produce additional orbiters has been retained by the implementation of the structural spares program.

This program, which continues through FY 1987, will provide major structural elements that could be used to repair one of the four orbiter or as parts for a fifth orbiter.

This approach, coupled with the ongoing orbiter spares program, retains production capability at the prime and subcontractor level for the next few years.

Costs for procurement of a fifth orbiter is estimated as follows:

FY 1985 start - June 1980 delivery:	$1943 million
FY 1986 start - June 1990 delivery:	$2176 million
FY 1987 start - June 1991 delivery:	$2399 million

QUESTION 9:

In accordance with Rule XI, Clause 2(1)(4) of the Rules of the House of Representatives, the Committee is required to include in the report accompanying the NASA authorization bill an assessment of the impact of the legislation on inflation. Please provide the Committee with any information or reports which would be useful to the Committee in fulfilling this requirement.

ANSWER:

Effect of Legislation on Inflation:

In accordance with Rule XI, Clause 2(1)(4) of the Rules of the House of Representatives this legislation is assessed to have no adverse long-run inflationary effects on prices and cost in the operation of the national economy. NASA expenditures are labor intensive, with approximately 80 percent of spending directly for jobs and the remainder for materials. NASA employs about 22,000 civil servants and supports about 120,000 contractor and support services employees. Assuming a multiplier effect 2.5, the total, short-run employment effect on the United States' economy is about 355,000 jobs. This represents less than one-half of one percent of the total civilian labor force in the United States--too small to have a significant national effect, although there could be some specific cases of industrial and regional employment and price changes influenced by NASA expenditures.

One of the most significant economic effects of NASA spending is the long-run productivity advance from new technologies developed for the space and aeronautics programs. Many NASA-sponsored advances in air and space and transportation, communications satellites, remote sensing satellites, and other innovations have improved the productive capacity of industry and stimulated the development and growth of many new businesses.

NASA is actively pursuing its role to expand the opportunities for private industry to provide and gain access into space effectively and economically use space for commercial ventures. These expanded business opportunities have stimulated and are expected to continue to stimulate more productive, non-inflationary private sector economic growth, job creation and improve the United States competitive economic position in the world, e.g., improve United States trade balance.

Although it is difficult to assess the results of the various macro-economic studies of the effects of NASA spending on the GNP, it is generally believed from the analyses done by the Midwest Research Institute, Mathematica, Inc., and others, that NASA high technology R&D expenditures have returned more to the economy in substantial and long-lasting productivity gains than has been spent. Since these gains are through spinoff commercial advances, they are "extra" returns above and beyond the primary goal of NASA programs: the successful completion of the various R&D mission assignments to meet public sector needs. Therefore, any gains which show positive economic returns in the long run indicate a non-inflationary, significant return to the citizens of the United States.

QUESTION 10:

Please provide a summary of the Space Shuttle operational capabilities that were originally proposed at the beginning of the program as compared to the operational capabilities which currently exist. This summary should include but not be limited to payload launch capability (ETR and WTR), flight rate capability, on-orbit stay time, cost per flight, and orbiter turnaround time. This summary should also include a schedule for planned performance improvements.

ANSWER:

Item	Originally Proposed	Current Capability
(1) Payload launch Capability		
WTR	32,000 lbs.	Still planned on maximum of 32,000 lbs.
ETR	65,000 lbs.	65,000 lbs.
(2) Flight Rate Capability	60 flights per year	KSC Flights only: FY 1984 scheduled 8 flights. Based on 35 workday turnaround, target is 17 flights/year (by end of FY 1985). Based on 28 workday turnaround, target is 21 flights/year (by end of FY 1985).
(3) On-orbit stay time	7 days (4 in crew) for self sustaining lifetime. Up to 30 days by adding expendables.	10 days. The capability for adding more time is currently under review. Consumables are the limiting factor.

Item	Originally Proposed	Current Capability
(4) Cost per flight	$18 million (FY 1975 dollars), Average of 572 flights over 12 years.	Projected approximately $60 million (FY 1975 dollars), Average of 232 flights over 12 years.
(5) Orbiter Turnaround Time	Less than 160 working hours covering 14 calendar days.	Best to date was STS-8: 55 workdays. Target for end of FY 1984 is 35 workdays. Target for end of FY 1985 is 28 workdays.

TABLE A (Revised)

COMPARISON OF OMB BUDGET REQUEST TO CONGRESSIONAL BUDGET REQUEST

RESEARCH AND DEVELOPMENT	FY 1984 Current Estimate	FY 1985 Budget Request to OMB	Δ	FY 1985 Budget Request to Congress	Remarks
Space Station	(14.0)*	235.0	-85.0	150.0	Reduced level of proposed funding for new initiative.
Space Transportation Capability Dev.	431.7	384.0	-22.6	361.4	
Spacelab	112.5	69.3	--	69.3	
Upper Stages	143.2	98.3	-5.9	92.4	Reduction of funds reflects cancellation of PAM-A vehicle for ACTS and cancellation of proposed Centaur for TDRS-F.
Engineering & Technical Base	93.1	107.4	-1.7	105.7	Reduced level of funding reflects reduction in Marshall Space Flight Center's computer equipment procurement.
Payload Operations & Support Equip.	59.6	61.3	--	61.3	

*In FY 1984, the Space Station activity is included in the following: $6.0 million in Space Transportation Capability Development; $2.0 million in Space Science and Applications, and $6.0 million in Space Research and Technology.

	FY 1984 Current Estimate	FY 1985 Budget Request to OMB	Δ	FY 1985 Budget Request to Congress	Remarks
Advanced Programs	20.0	19.5	-5.0	14.5	Reduced level of augmentation in base program.
Tethered Satellite System	3.3	18.2	--	18.2	
Orbital Maneuvering Vehicle	--	10.0	-10.0	--	Deferred for possible re-submittal in FY 86 budget.
Physics & Astronomy	567.6	709.5	-32.3	677.2	
Space Telescope Development	195.6	195.0	--	195.0	
Gamma Ray Observatory	86.2	120.2	--	120.2	
Spacelab Payload Development and Mission Management	80.9	111.4	-6.0	105.4	Reduction of funds for proposed augmentation.
Space Plasma Laboratory	--	5.0	-5.0	--	Deletion of funds for proposed augmentation.
Explorer Development	48.7	51.9	--	51.9	
Mission Operations and Data Analysis	68.1	110.5	-1.4	109.1	Reduction of funds for proposed augmentation.
Research and Analysis	35.8	53.9	-17.0	36.9	Reduction of funds for proposed augmentation.
Suborbital	52.3	61.6	-2.9	58.7	Reduction of funds for proposed augmentation.

	FY 1984 Current Estimate	FY 1985 Budget Request to OMB	Δ	FY 1985 Budget Request to Congress	Remarks
Life Sciences	58.0	70.0	-6.7	63.3	
Flight Experiments	23.0	27.1	--	27.1	
Research and Analysis	35.0	36.2	--	36.2	
Life Science Mid-Deck Experiments	--	2.7	-2.7	--	Deletion of funds for proposed augmentation.
Space Adaptation Syndrome	---	4.0	-4.0	--	Deletion of funds for proposed augmentation.
Planetary Exploration	217.4	298.9	-12.0	286.9	
Galileo Development	79.5	56.1	--	56.1	
International Solar Polar Mission Development	6.0	9.0	--	9.0	
Venus Radar Mapper Development	29.0	92.5	--	92.5	
MARS Geoscience/Climatology Orbiter	--	16.0	--	16.0	
Mission Operations and Data Analysis	43.4	61.8	-3.0	58.8	Reduction of funds for proposed augmentation.
Research and Analysis	59.5	63.5	-9.0	54.5	Reduction of funds for proposed augmentation.
Space Applications	291.0	471.6	-127.5	344.1	
Landsat-4	16.8	--	--	--	
Shuttle Payloads	16.0	22.6	-4.5	18.1	Reduction of funds for proposed augmentation.

	FY 1984 Current Estimate	FY 1985 Budget Request to OMB	Δ	FY 1985 Budget Request to Congress	Remarks
Geodynamics	20.5	28.6	-6.7	21.9	Deletion of funds for proposed augmentation.
Laser Network Operations	7.5	8.0	--	8.0	
Solid Earth Observations Research and Analysis	14.6	15.6	--	15.6	
Environmental Observations Research and Analysis	90.9	100.6	-4.0	96.6	Reduction of funds for proposed augmentations.
Environmental Observations Shuttle Payloads	7.6	7.8	--	7.8	
Tethered Satellite Payloads	--	3.0	--	3.0	
Earth Radiation Budget Experiment	15.5	8.1	--	8.1	
Upper Atmosphere Research Satellite Mission	20.0	60.7	--	60.7	
Scatterometer	--	15.0	--	15.0	
Other Environmental Observations	28.0	35.2	-5.7	29.5	Deletion of funds for proposed augmentation.
Materials Processing	23.6	27.6	-4.6	23.0	Reduction of funds for proposed augmentation.
Search and Rescue	3.8	2.4	--	2.4	
Advanced Communications Technology Satellite	5.0	92.0	-87.0	5.0	Deletion of funds for contractor start on development of ACTS.

	FY 1984 Current Estimate	FY 1985 Budget Request to OMB	△	FY 1985 Budget Request to Congress	Remarks
Other Communications	12.3	20.2	-7.0	13.2	Reduction of funds for proposed augmentation.
Information Systems	8.9	19.2	-3.0	16.2	Reduction of funds for proposed augmentation.
Commercialization	--	5.0	-5.0	--	Deletion of funds for proposed augmentation.
Technology Utilization	9.0	12.0	-2.5	9.5	Deletion of funds for proposed augmentation.
Aeronautical Research & Technology	302.3	384.7	-42.3	342.4	
Ongoing Research & Technology Base	215.8	233.3	--	233.3	
Ongoing Systems Technology	86.5	119.4	-10.3	109.1	Deletion of funds for ongoing systems tech. programs-Guidance & Navigation, and RSRA Flight Research/Rotors. Reduction of funding for Advanced Composite Structures and Advanced Turboprop Systems.
Advanced Turboprop Program (Phase III) Aug.	--	25.0	-25.0	--	Deletion of funds for systems tech. program augmentation.
Small Engine Component Technology Augmentation	--	5.0	-5.0	--	Deletion of funds for systems technology program augmentation.

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	FY 1984 Current Estimate	FY 1985 Budget Request to OMB	Δ	FY 1985 Budget Request to Congress	Remarks
Ceramics for Turbine Engines	--	2.0	-2.0	--	Deletion of funds for systems technology program augmentation.
Space Research & Technology	132.4	165.5	-20.4	145.1	
Ongoing Research & Technology Base	125.4	136.0	--	136.0	
Ongoing Systems Technology	7.0	14.5	-5.4	9.1	Increase in Space Flight Experiments ($.5M), and reduction to proposed augmentation for Advanced SSME Technology.
In-Space Flight Research Aug.	--	15.0	-15.0	--	Deletion of funds for systems technology program augmentation.
Standards and Practices	4.6	7.9	-3.0	4.9	Deletion of proposed augmentations for space radiation effects and composite materials defects studies.
Tracking and Data Advanced Systems	14.2	15.3	--	15.3	
Small Business	--	25.0	-25.0	--	Deletion of separate funding for SBIR.
TOTAL RESEARCH AND DEVELOPMENT	2028.2	2779.4	-379.3	2400.1	

	FY 1984 Current Estimate	FY 1985 Budget Request to OMB	Δ	FY 1985 Budget Request to Congress	Remarks
SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS					
Shuttle Production & Operational Cap.	1649.3	1542.0	-76.4	1465.6	
Orbiter	716.3	619.0	-12.2	606.8	Reduced level of funding for program reserves.
Launch and Mission Support	277.7	253.5	-18.7	234.8	Reduced level of funding for program reserves.
Propulsion Systems	618.0	607.0	-8.0	599.0	Reduced level of funding for program reserves.
Changes/Systems Upgrade	37.3	62.5	-37.5	25.0	Application of general reduction.
Space Transportation Operations	1452.0	1454.0	-115.0	1339.0	
Shuttle Operations	1402.0	1454.0	-115.0	1339.0	Reduced level of funding reflects deletion of STS-12, and an increase in anticipated reimbursements.
Expendable Launch Vehicles	50.0	--	--	--	
Space & Ground Network, Communications and Data Systems	674.0	811.0	-15.3	795.7	
Space Network	259.1	395.3	-8.8	386.5	Reduction of augmentations for TDRS Support.
Ground Network	249.3	226.8	-3.2	223.6	Operations of Moffett Field Complex funding removed.

	FY 1984 Current Estimate	FY 1985 Budget Request to OMB	△	FY 1985 Budget Request to Congress	Remarks
Communications & Data Systems	165.6	188.9	-3.3	185.6	Reduction in augmentations to data processing support and to new projects.
TOTAL SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS	3775.3	3807.0	-206.7	3600.3	
CONSTRUCTION OF FACILITIES	155.5	197.3	-37.3	160.0	
Projects Approved		161.9	-1.9	160.0	Reduction of proposed level of funding.
Modification of Test Position 115 for High Pressure Cryogenic Component Testing (MSFC)		1.8	-1.8	--	Deletion of funds to modify facility for testing and evaluating high pressure engine components, instrumentation systems, and combustors.
Construction of Addition to Orbiter Processing Facility Annex (KSC)		2.7	-2.7	--	Deletion of funds to provide additional support space for the operational processing of the STS Orbiter.
Installation of Cabling from Assembly Building Repeater Station to Pad B (KSC)		.7	-.7	--	Deletion of funds for the installation of fiber optic cables.

	FY 1984 Current Estimate	FY 1985 Budget Request to OMB	Δ	FY 1985 Budget Request to Congress	Remarks
Construction of Addition to Hangar AM (KSC)		.4	-.4	--	Deletion of funds for additional space to protect the payload processing environment during loading and unloading.
Construction of Payload Control Rooms (KSC)		1.2	-1.2	--	Deletion of funds to provide additional space for payload user personnel.
Construction of Spacecraft/ Payload Integration and Refurbishment Facility (GSFC)		15.0	-15.0	--	Deletion of funds for the construction of various support areas to provide the capability for processing and integrating full shuttle payloads.
Modifications for Horizontal Payload Operations (KSC)		2.1	-2.1	--	Deletion of funds for the fabrication and installation of a second set of horizontal payload processing hardware in the Operations and Checkout (O&C) Bldg., Assembly and Test area, and the conversion of the O&C Building vacuum pump room, logistics room and machine shop, and to provide additional storage areas for Spacelab flight hardware.

	FY 1984 Current Estimate	FY 1985 Budget Request to OMB	Δ	FY 1985 Budget Request to Congress	Remarks
Modifications to 16-Foot Transonic Tunnel (LaRC)		4.7	-4.7	--	Deletion of funds for modifications of propulsion system to provide model preparation area, semi-span model support system, a dual flow propulsion testing capability, and a drive system liquid rheostat.
Construction of Antenna Technology Laboratory (LeRC)		6.8	-6.8	--	Deletion of funds for construction of a facility to house equipment and computers to provide for advanced research and development of large space/ground antennae and related hardware.
RESEARCH AND PROGRAM MANAGEMENT	1258.5**	1373.0**	-42.0	1331.0**	Deletion of funds for increase in civil service ceiling requested, proposed augmentations in personnel and laboratory equipment replacement. Reduction in increase for operational maintenance enhancement. Reduction associated with the government-wide initiative to reduce the number of GS/GM 11-15 positions, and a reduction in proposed inflation rate.
(R&PM Base)	(1258.5)	(1343.0)	(-22.0)	(1321.0)	
(Laboratory Equipment)	(--)	(10.0)	(-10.0)	(--)	
(Operational Maintenance)	(--)	(20.0)	(-10.0)	(10.0)	
TOTAL NASA	**7217.5**	**8156.7**	**-665.3**	**7491.4**	

**Includes adjustment to present pay rates

TABLE B

National Aeronautics and Space Administration
FY 1985 Budget Request
Research and Development/Space Flight, Control and Data Communications

HEADQUARTERS
(millions of dollars)

	FY 1984 Current Estimate	FY 1985 Center Request	Δ	FY 1985 Budget Request	Remarks
Space Station	(14.0)[1/]	235.0	-85.0	150.0[2/]	Decrease to proposed level of funding.
Space Transportation Capability Dev.	48.0	30.0	--	30.0	
Shuttle Production & Operational Cap.*	87.6	75.2	+18.0	93.2	Increase reflects added development effort on Extravehicular Mobility Unit and SSME.
Space Transportation Operations*	29.1	51.7	--	51.7	
Small Business	--	25.0	-25.0	--	Deletion of separate funding.
Physics and Astronomy	29.6	42.4	--	42.4	
Life Sciences	13.2	11.4	--	11.4	
Planetary Exploration	43.4	29.0	--	29.0	
Space Applications	30.3	32.5	--	32.5	
Technology Utilization	5.4	5.5	--	5.5	
Aeronautics Research and Technology	7.2	7.5	--	7.5	
Space Research and Technology	7.9	8.2	--	8.2	

	FY 1984 Current Estimate	FY 1985 Center Request	△	FY 1985 Budget Request	Remarks
Space and Ground Network Communications and Data Systems*	204.9	228.2	--	228.2	
TOTAL	506.6	781.6	-92.0	689.6	

1/In FY 1984, the Space Station Activity is included in the following: $6.0 million in Space Transportation Capability Development; $2.0 million in Space Science and Applications; and $6.0 million in Space Research and Technology.
2/The FY 1985 funding is shown at Headquarters pending implementation decisions on the individual program activity elements and related field center assignments.

*Space Flight, Control and Data-Communications appropriation

National Aeronautics and Space Administration
FY 1985 Budget Request
Research and Development/Space Flight, Control and Data Communications

AMES RESEARCH CENTER
(millions of dollars)

	FY 1984 Current Estimate	FY 1985 Center Request	Δ	FY 1985 Budget Request	Remarks
Space Transportation Operations	2.3	2.5	—	2.5	
Physics and Astronomy	20.8	29.3	-8.0	21.3	Deletion of proposed start of the Shuttle Infrared Telescope Facility in FY 1985.
Life Sciences	21.4	24.4	—	24.4	
Planetary Exploration	16.6	12.1	—	12.1	
Space Applications	5.5	5.9	—	5.9	
Technology Utilization	.1	.2	—	.2	
Aeronautical Research & Technology	121.1	152.8	-18.1	134.7	Reduction to proposed level of funding for R&T Base. Deletion of ongoing Guidance and Navigation and RSRA Flight Research/ Rotor Systems Technology programs. Deletion of proposed augmentations: Advanced Tilt Rotor Technology, Aircraft Electric Power Systems, Aircraft Safety Research, and Oblique Wing Transonic Technology.
Space Research and Technology	12.8	13.5	—	13.5	
Space and Ground Network Communications and Data Systems*	6.5	9.6	-.9	8.7	Reduction of funds for equipment deferrals.
TOTAL	207.1	250.3	27.0	223.3	

*Space Flight, Control and Data Communications appropriation

National Aeronautics and Space Administration
FY 1985 Budget Request
Research and Development/Space Flight, Control and Data Communications

GEORGE C. MARSHALL SPACE FLIGHT CENTER
(millions of dollars)

	FY 1984 Current Estimate	FY 1985 Center Request	△	FY 1985 Budget Request	Remarks
Space Transportation Capability Dev.	107.1	87.0	-6.0	81.0	Deleted planned TOS upper stage procurement; reduced center reserves; and added OMV phase B study.
Shuttle Production and Operational Cap.*	614.5	597.3	-9.0	588.3	Reduction of funds reflects reduced external tank tooling and producibility efforts; reduced anticipated inflation; expanded SSME development effort and deleted one production SSME.
Space Transportation Operations*	642.5	807.8	-136.0	671.8	Reduced hardware procurements as the result of deleting flights; reduced center reserves; rephase spare and hardware delivery schedules; and reduced anticipated inflation provisions.
Physics and Astronomy	294.4	342.3	-5.4	336.9	Deletion of funding for Space Plasma Lab instrumentation augmentation.
Space Applications	15.8	18.9	-2.1	16.8	Reduction of proposed funding level for development of Advanced Automatic Directional Solidification Furnace as a result of later launch opportunity than Center assumed.
Technology Utilization	.4	.5	—	.5	
Aeronautical Research and Technology	.4	1.7	-1.2	.5	Reduction to proposed level of funding for the R&T Base. Deletion of Aircraft Electric Power Systems proposed augmentation.

	FY 1984 Current Estimate	FY 1985 Center Request	△	FY 1985 Budget Request	Remarks
Space Research and Technology	14.3	23.9	-7.4	16.5	Reduction to proposed level of funding for Advanced SSME Technology. Deletion of In-Space Flight Research proposed augmentation.
Space and Ground Network Communications and Data System*	13.5	20.5	-3.1	17.4	Reduced level of funding for Program Support Communications.
TOTAL	1702.9	1899.9	-170.2	1729.7	

*Space Flight, Control and Data Communications appropriation

National Aeronautics and Space Administration
FY 1985 Budget Request
Research and Development/Space Flight, Control and Data Communications

GODDARD SPACE FLIGHT CENTER
(millions of dollars)

	FY 1984 Current Estimate	FY 1985 Center Request	Δ	FY 1985 Budget Request	Remarks
Space Transportation Capability Dev.	.4	--	--	--	
Space Transportation Operations*	45.3	.6	--	.6	
Physics and Astronomy	186.5	252.5	-20.0	232.5	Reduction of funding for Solar Optical Telescope (SOT); the SOT will remain in definition phase through FY 1985.
Life Sciences	.1	.1	--	.1	
Planetary Exploration	3.9	3.4	--	3.4	
Space Applications	159.0	189.1	--	189.1	
Technology Utilization	.9	.8	--	.8	
Aeronautical Research and Technology	.3	.4	--	.4	
Space Research and Technology	8.8	12.2	-3.5	8.7	Deletion of In-Space Flight Research and Spacecraft Bus Technology proposed augmentations.
Tracking and Data Advanced Systems	4.5	4.8	--	4.8	
Space and Ground Network Communications and Data Systems*	352.7	429.3	+5.5	434.8	Increase funding for Centaur Upper Stage integration for TDRS-E launch and new start support for UARS.
TOTAL	762.4	893.2	-18.0	875.2	

*Space Flight, Control and Data Communications appropriation

National Aeronautics and Space Administration
FY 1985 Budget Request
Research and Development/Space Flight, Control and Data Communications

JET PROPULSION LABORATORY
(millions of dollars)

	FY 1984 Current Estimate	FY 1985 Center Request	Δ	FY 1985 Budget Request	Remarks
Space Transportation Capability Dev.	.7	.3	—	.3	
Space Transportation Operations*	.2	—	—	—	
Physics and Astronomy	17.6	26.3	—	26.3	
Life Sciences	1.3	1.7	—	1.7	
Planetary Exploration	144.5	224.3	+10.0	234.3	Increase for potential changes to Galileo spacecraft due to recent Voyager data which suggests a harsher radiation environment than previously anticipated.
Space Applications	49.6	68.1	—	68.1	
Technology Utilization	.5	.8	-.4	.4	Deletion of funds for robotics enhancement.
Aeronautical Research and Technology	.5	.5	—	.5	
Space Research and Technology	23.0	28.9	-6.2	22.7	Deletion of Spacecraft Bus, and Space Radiation Effects proposed augmentations. Deletion of baseline adjustments for technologies to discover and assess defects in composite materials.
Tracking and Data Advanced Systems	9.7	10.5	—	10.5	

	FY 1984 Current Estimate	FY 1985 Center Request	Δ	FY 1985 Budget Request	Remarks
Space and Ground Network Communications and Data Systems*	95.9	114.5	-7.9	106.6	Reduction of funds for equipment deferrals and deletions and operational reductions including training, testing and documentation.
TOTAL	343.5	475.9	-4.5	471.4	

*Space Flight, Control and Data Communications appropriation

National Aeronautics and Space Administration
FY 1985 Budget Request
Research and Development/Space Flight, Control and Data Communications

JOHNSON SPACE CENTER
(millions of dollars)

	FY 1984 Current Estimate	FY 1985 Center Request	Δ	FY 1985 Budget Request	Remarks
Space Transportation Capability Dev.	114.3	126.3	-11.0	115.3	Reduction of funds for proposed equipment augmentations and reprioritized advanced program studies.
Shuttle Production and Operational Cap.*	837.7	758.3	-61.0	697.3	Reduction of funds reflects reduced reserves; deferred and deleted specific orbiter spares line items; deferred equipment augmentations; added Pacific abort landing sites; and reduced requested sustaining engineering levels.
Space Transportation Operations*	392.5	421.9	-72.0	349.9	Reduced reserves and manpower transfer.
Physics and Astronomy	10.6	4.5	—	4.5	
Life Sciences	20.7	23.7	—	23.7	
Planetary Exploration	9.1	8.2	—	8.2	
Space Applications	5.5	6.1	—	6.1	
Technology Utilization	.1	.2	+.1	.3	Increased automation effort.
Aeronautical Research & Technology	1.2	1.2	—	1.2	
Space Research & Technology	13.5	16.5	-2.4	14.1	Deletion of In-Space Flight Research proposed augmentation.
Space and Ground Network Communications and Data Systems*	.5	—	—	—	
TOTAL	1405.7	1366.9	-146.3	1220.6	

*Space Flight, Control and Data Communications appropriation

National Aeronautics and Space Administration
FY 1985 Budget Request
Research and Development/Space Flight, Control and Data Communications

KENNEDY SPACE CENTER
(millions of dollars)

	FY 1984 Current Estimate	FY 1985 Center Request	Δ	FY 1985 Budget Request	Remarks
Space Transportation Capability Dev.	55.3	50.1	-7.0	43.1	Reduction of requested hardware augmentations.
Shuttle Production and Operational Cap.*	109.5	91.8	-5.0	86.8	Reduction of funds reflect deferral of capability improvement projects and added railroad restoration.
Space Transportation Operations*	340.1	303.0	-40.5	262.5	Reduction of funds reflects projected manpower savings based on flight experience and contractor consolidation, and reduced data management augmentation.
Physics and Astronomy	6.9	11.0	—	11.0	
Life Sciences	1.0	1.6	—	1.6	
Technology Utilization	.5	.5	-.2	.3	Reduction of support on remote sensing proposals.
Space Research and Technology	.6	.6	—	.6	
TOTAL	513.9	458.6	-52.7	405.9	

*Space Flight, Control and Data Communications appropriation

84-202 O—84—66

National Aeronautics and Space Administration
FY 1985 Budget Request
Research and Development/Space Flight, Control and Data Communications

LANGLEY RESEARCH CENTER
(millions of dollars)

	FY 1984 Current Estimate	FY 1985 Center Request	△	FY 1985 Budget Request	Remarks
Space Transportation Capability Dev.	.7	.1	—	.1	
Physics and Astronomy	1.1	2.2	—	2.2	
Life Sciences	.3	.4	—	.4	
Space Applications	9.8	8.6	—	8.6	
Technology Utilization	.7	.6	+.3	.9	Increased materials effort.
Aeronautical Research and Technology	93.9	128.4	-12.3	116.1	Reduction to proposed level of funding for the R&T Base. Reduction to ongoing Advanced Composite Structures Systems Technology program. Deletion of proposed augmentations: Aircraft Electric Power Systems and Aircraft Safety Research.
Space Research and Technology	28.8	49.6	-16.7	32.9	Deletion of In-Space Flight Research proposed augmentation.
TOTAL	135.3	189.9	-28.7	161.2	

National Aeronautics and Space Administration
FY 1985 Budget Request
Research and Development/Space Flight, Control and Data Communications

LEWIS RESEARCH CENTER
(millions of dollars)

	FY 1984 Current Estimate	FY 1985 Center Request	△	FY 1985 Budget Request	Remarks
Space Transportation Capability Dev.	98.2	86.0	-1.0	85.0	Reduction of funds reflects deletion of proposed additions to Centaur program; reductions offset partially by adding TDRSS-E Centaur vehicle integration.
Space Applications	14.3	105.6	-90.0	15.6	Restructuring of the Advanced Communications Technology Satellite program from a flight program to a technology development and ground test program.
Technology Utilization	.2	.2	+.2	.4	Increased electronics effort.
Aeronautical Research and Technology	77.7	128.9	-47.4	81.5	Reduction to ongoing Advanced Turboprop Systems Technology program. Deletion of proposed augmentations: Advanced Turboprop Program (Phase III), Small Engine Component Technology, Ceramics for Turbine Engines, Aircraft Electric Power Systems, and Aircraft Safety Research.
Space Research and Technology	27.3	49.6	-16.8	32.8	Reduction to proposed level of funding for Advanced SSME Technology. Deletion of In-Space Flight Research, Spacecraft Bus Systems Technology, and OTV Technology proposed augmentations.
TOTAL	217.7	370.3	-155.0	215.3	

National Aeronautics and Space Administration
FY 1985 Budget Request
Research and Development/Space Flight, Control and Data Communications

NATIONAL SPACE TECHNOLOGY LABORATORIES
(millions of dollars)

	FY 1984 Current Estimate	FY 1985 Center Request	Δ	FY 1985 Budget Request	Remarks
Space Transportation Capability Dev.	7.0	6.6	--	6.6	
Space Applications	1.3	1.4	--	1.4	
Technology Utilization	.1	.2	--	.2	
TOTAL	8.4	8.2	--	8.2	

Table C

National Aeronautics and Space Administration

FY 1983 AND FY 1984 OPERATING PLANS
BY BUDGET LINE ITEM
(Dollars in Millions)

	FY 1983	FY 1984
Research & Development		
Space Transportation Capability Development	415.5	431.7
Physics and Astronomy	470.3	567.6
Life Sciences	55.7	58.0
Planetary Exploration	186.4	217.4
Space Applications	347.7	291.0
Technology Utilization	9.0	9.0
Aeronautical Research and Technology	280.0	302.3
Space Research and Technology	124.5	137.0
Tracking and Data Advanced Systems	13.4	14.2
TOTAL RESEARCH AND DEVELOPMENT	1902.5	2028.2
Space Flight, Control and Data Communications		
Shuttle Production and Operational Capability	1725.8	1649.3
Space Transportation Operations	1421.7	1452.0
Space & Ground Network, Communications and Data Systems	485.5	674.0
TOTAL SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS	3633.0	3775.3
CONSTRUCTION OF FACILITIES	103.5	155.5[a/]
RESEARCH AND PROGRAM MANAGEMENT	1197.4	1258.5[b/]
TOTAL NASA	6836.4	7217.5

NOTE: These amounts are presented in the line item structure of the FY 1985 budget. The FY 1984 amounts are consistent with the Operating Plan transmitted to the Committees on 9/30/83, except as noted.

a/ General Supplemental of $20M for construction of a Solid Rocket Booster processing facility and a Shuttle Processing Contract warehousing facility.

b/ Includes $20M proposed supplemental appropriation to partially cover cost of revised salary rates effective in January 1984, and increased Agency costs for health insurance.

National Aeronautics and Space Administration

Estimated Total Project Cost

(In Millions of Dollars)

Table D

	Original Development Estimate		Current Estimate
	Date	Range	Range
Space Telescope (ST) Development	2/78	565-611 (a)	1175 (a)
International Solar Polar Mission (ISPM) Development	1/83	120-140	120-140
ISPM Mission Ops. & Data Analysis	1/83	20-30	20-30
Gamma Ray Observatory (GRO) Development	1/83	395-435	395-435
GRO Mission Ops. & Data Analysis	1/83	30-40	30-40
Galileo Development	1/83	650-700	650-700
Galileo Ops. & Data Analysis	1/83	180-210	180/210
Venus Radar Mapper (VRM) Mission Development	1/83 (b)	320-350 (b)	320-350 (b)
VRM Mission Ops. & Data Analysis		30-50 (b)	30-50 (b)
Earth Radiation Budget Experiment (ERBE)	1/83	110-130	110-130
Advanced Communications Technology Satellite (ACTS) project	1/83 (b)	325-425 (b)	(c)
Tethered Satellite	1/83 (b)	40-50 (b)	50-60 (d)
Upper Atmosphere Research Satellite (UARS)	1/84	630-700 (b)	630-700 (b)
Mars Geoscience/Climatology Orbiter (MGCO)	1/84	300-375 (b)	300-375 (b)
Scatterometer	1/84	120-135 (b)	120-135 (b)

(a) Original Space Telescope estimate, which supported a late 1983 launch, was stated in FY 1978 budget dollars, to be updated annually; this estimate has been updated to reflect real year dollars. The increase reflected by the current estimate is due to continuing development problems and a series of launch slips from late 1983 to the second half of 1986.

(b) Planning estimate; development estimate not yet available.

(c) The Advanced Communications Technology Satellite (ACTS) project has been restructured to delete the flight mission; the program now includes only technology development and ground testing of components which are required for future communications satellites.

(d) This estimate has been increased due to better definition of the technical requirements.

Table E

National Aeronautics and Space Administration

EFFECT OF INFLATION ON NASA BUDGET
COMPARATIVE PURCHASING POWER INDICES BY 1978 - 1984

	GNP Price Deflator (%) [1]	NASA Aerospace Price Deflator (%) [2]	Budget Outlays - Millions of Dollars	
			Actuals	Constant FY 1973 [3]
FY 1973	100.0	100.0	3315	3315
FY 1974	91.9	93.3	3256	3038
FY 1975	84.1	84.2	3267	2297
FY 1976	79.9	77.2	3669	2832
FY 1977	75.6	69.7	3945	2750
FY 1978	70.3	64.7	3983	2577
FY 1979	64.8	59.1	4197	2480
FY 1980	59.3	53.4	4850	2590
FY 1981	54.2	48.2	5426	2615
FY 1982	51.2	44.0	6035	2655
FY 1983 [4]	49.0	41.5	6664	2766
FY 1984 [4]	47.0	39.0	7068	2757
FY 1985 [4]	44.8	36.7	7370	2705

1/ Economic Indicators, December 1983, year over year growth.
2/ Reflects labor intensive nature of NASA purchases using aerospace related inflation data.
3/ Constant FY 1973 outlays calculated using the NASA Aerospace Price Deflator.
4/ Current estimates.

TABLE F

National Aeronautics and Space Administration

EFFECT OF INFLATION ON SHUTTLE DEVELOPMENT COSTS
(millions of dollars)

	Baseline Estimate FY 1971 Dollars	Current Estimate FY 1971 Dollars	Current Estimate Inflated Dollars	Impact of Inflation on Current Estimate
Design, Development, Test & Evaluation (DDT&E)	$5,150	$6,745	$10,078	$3,333

TABLE G

National Aeronautics and Space Administration

UNOBLIGATED BALANCE

(Millions of Dollars)

	FY 1983 & Prior Unobligated Balance 9/30/83	FY 1984 Unobligated Balance as of 12/31/83	Estimated Unobligated Balance 9/30/84
Research and Development			
Space Transportation Capability Development	121.6	377.9	20.6
Physics and Astronomy	55.5	447.1	27.0
Life Sciences	3.2	45.9	2.9
Planetary Exploration	15.7	165.0	10.4
Space Applications	68.5	249.0	14.0
Technology Utilization	3.1	8.3	.4
Aeronautical Research and Technology	35.7	219.4	15.1
Space Research and Technology	13.0	101.4	6.8
Tracking and Data Advanced Systems	1.9	8.4	.7
TOTAL RESEARCH AND DEVELOPMENT	318.2	1622.4	97.9
Space Flight, Control and Data Communications			
Shuttle Production and Operational Capability	53.1	1191.2	82.5
Space Transportation Operations	41.8	968.2	72.6
Space & Ground Network Communications & Data Systems	56.7	407.7	33.7
TOTAL SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS	151.6	2567.1	188.8
CONSTRUCTION OF FACILITIES	111.2	152.7	84.7
RESEARCH AND PROGRAM MANAGEMENT	--	922.9 a/	--
TOTAL NASA	**581.0**	**5265.1**	**371.4**

All Research and Program Management funds are planned for obligation by the end of FY 1984. A small portion of the R&D and SFCDC funds will remain unobligated in the procurement pipeline at the end of the fiscal year. This amount, statistically equivalent to a few weeks of procurement activity, will be obligated in the next fiscal year. These amounts in the procurement pipeline have no impact on the following fiscal year requirements. For Construction of Facilities, it is estimated that $116.6 million of the FY 1984 appropriation of $155.5 million will be obligated in FY 1984, leaving an unobligated balance of $38.9 million. In addition, $45.8 million of prior appropriations are estimated to be unobligated at the end of the year.

a/ Includes $20 million proposed supplemental appropriation to partially cover revised salary rates effective in FY 1984 and increased Agency costs for health insurance.

APPENDIX 2

OFFICE OF SPACE FLIGHT

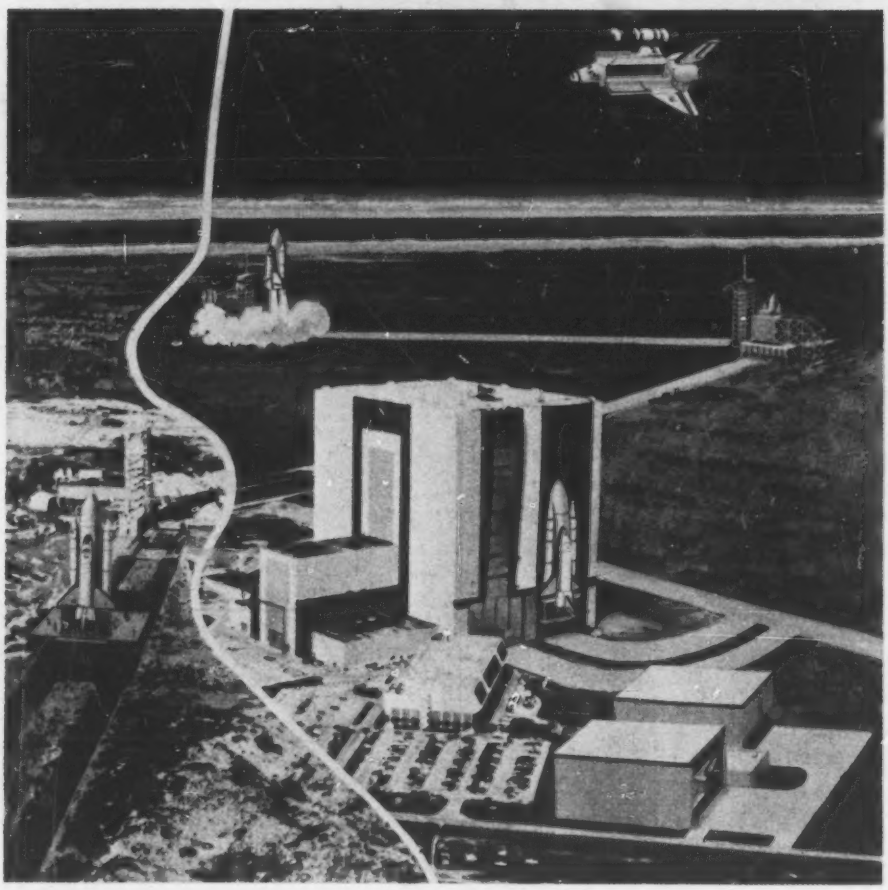
NASA

A REVIEW

Sensitivities and costs as related to an enlarged STS Orbiter Fleet

A REPORT TO THE CONGRESS

JANUARY 1984



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Appendix A: Contractor's Budget and Planning Letter for Procuring Additional Orbiters

NOTE: Data as of June 1983

I. SUMMARY

NASA has periodically reviewed the sensitivities and costs associated with requirements for additional orbiters. In 1982, NASA completed the initial internal and contractor cost analyses for procurement of additional orbiters. In addition to these efforts an Interagency Space Launch Policy Working Group independently reviewed the need for a fifth orbiter as part of the FY 1984 budget process. This report presents the status of these sensitivities and cost analyses.

Both NASA and the policy working group reached a similar conclusion that the currently authorized four orbiter fleet should be capable of meeting projected launch demands through the remainder of this decade. However, an emerging theme from both reviews was the need for launch assurance in the late 1980's as the projected mission model becomes denser and the impact of an orbiter loss or major damage becomes more severe. Depending on assumptions, a four orbiter fleet with structural spares can provide acceptable assurance in this time period if one orbiter is lost or is down for an extended period of time. It was recognized that the future demand for Shuttle launches warranted some near-term action to provide both additional hardware and a level of base production support without committing to a $2.2 billion fifth orbiter.

Recognizing the above factors, an alternative approach was implemented which was to procure major structural spares that could serve as spares to the four orbiter fleet in case of major structural damage, maintain an ongoing level of production, and partially preserve the option for later procurement of additional orbiters, if required. This approach was approved by the President, included in the President's FY 1984 budget recommendation to the Congress, and subsequently approved in the 1984 Congressional actions.

The cost of procuring replacement or additional Orbiters has been estimated by Rockwell International, as well as by an independent NASA team. Rockwell estimated the cost (exclusive of the main engines and Government furnished equipment) for a leadtime away procurement of OV-105 and OV-106, being delivered in 1987 and 1988 respectively, would be $3035 million. (Leadtime away is a procurement approach which plans for completion of elements as they are required for final assembly). NASA's independent assessment team was in general agreement with the contractor's total estimate. The estimates were based on a January 1983 authority to proceed in order to minimize any increased costs at the prime contractor and the subcontractors for losses in

production capabilities. Both agreed that the least cost approach to procurement of additional Orbiters would be a block buy. The contractor estimated a reduction of $238 million of the $3035 million might be realized for a procurement (termed "block buy") which procured and fabricated two orbiters on a more concurrent basis.

NASA also reviewed what actions had already been taken as well as new means to reduce the costs of the current production program. For example, changes are being made to streamline contractual documents to reduce overhead and support costs. Restructuring the current contract to one with incentives to effect more cost savings was also studied. Changes and improvements in production methods and materials have been made. Some examples of these improvements are expanded use of numerically controlled machines, a computer aided design/manufacturing system, and the use of a new Thermal Protection System (TPS) material; all of these are expected to reduce the production time. Minimization of configuration changes is being pursued to hold down the production costs. Finally, and very importantly, increased management emphasis on cost reduction is being applied across all levels of the program. These efforts are already providing dividends to the program.

The following sections review in detail the key elements affecting the requirements and phasing for a fifth orbiter.

II. REVIEW OF SENSITIVITIES FOR ADDITIONAL ORBITERS

This section reviews the requirements which drive the demand for orbiters. The factors include orbiter turnaround time, customer demand to support projected launch-rate growth, and launch assurance.

A. Orbiter Turnaround Time

Figure 1 shows the projected improvement in KSC ground turnaround time as experience is gained and as improvements in processing procedures and hardware are made, and the resulting launch capability expressed in number of flights per year from each Orbiter as a function of time. The interval between launches for an Orbiter vehicle is made up of on-orbit mission time, ferry time if applicable, and processing time required to service the Orbiter, integrate the payload, and check out the systems prior to launch. The figure reflects a projection of standard launch service/maintenance requirements with a proportionate allowance for Sundays, holidays, and periodic (non-standard) significant scheduled tasks. The theoretical capability does not consider scheduling problems between KSC and VAFB and launch window requirements which will affect the operational capability of the fleet.

FIGURE 1. SHUTTLE LAUNCH TURNAROUND TIME

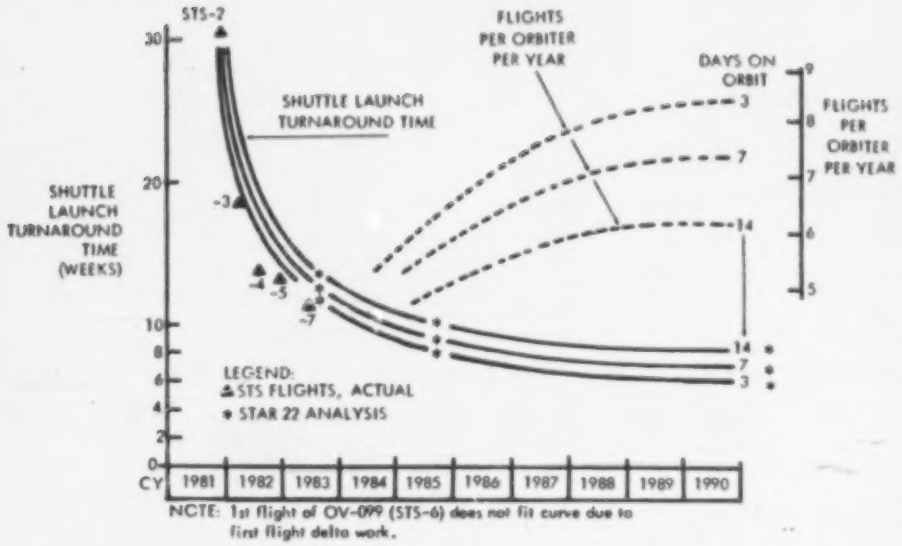

FIGURE 1

The planned Shuttle launch turnaround time decreases dramatically in the near term and continues to decrease out through the 1988 timeframe. The Space Shuttle flights 2, 3, 4, 5 and 7, tend to substantiate this projection. Figure 1 also shows the sensitivity of Orbiter availability as a function of on-orbit mission duration and demonstrates that extended duration missions require a larger Orbiter fleet to assure the same system availability. The curve shows that with 3-day missions there is a theoretical capability of approximately 8 flights per year/per Orbiter with an average 7-day mission approximately 7 flights per year/per Orbiter and with 14-day missions about 6 flights per

year per Orbiter can be expected. The projections of turnaround time include the estimated learning associated with Shuttle operations maturity.

B. Projected Launch Growth

The growth in the Shuttle launch demand for the period beyond 1986 is a function of a number of variables: the price charged the customer for a launch, the competition for providing launch services to deployable spacecraft from foreign and domestic expendable launch vehicles, the realization of potential uses of the Shuttle for materials processing and other new developments and, the capability of the Shuttle to meet launch demands. These are significant variables in terms of their potential impact upon launch demand. The competition from expendable launch vehicles, if these can be attractively priced, will reduce the Shuttle flight rate, but the magnitude of the reduction has not been fully determined.

Figure 2 illustrates the forecast of Shuttle projected mission growth in equivalent Shuttle flights based on a number of available traffic model information sources. Sources include Battelle Institute studies, Shuttle and expendable launch vehicle manifests, and Air Force planning documents, as well as other user literature such as that relating specifically to satellite communications. It should be noted that these models in the past have been overly optimistic; in recognition of this, NASA has

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decreased the flight projection from earlier estimates of sixty flights per year to the current twenty-four flights per year. These forecasts do not necessarily represent Shuttle demand because, for example, they do not consider competition to the Shuttle from domestic expendable launch vehicles that could materialize in the late 1980's.

FIGURE 2. PROJECTED SHUTTLE MISSIONS

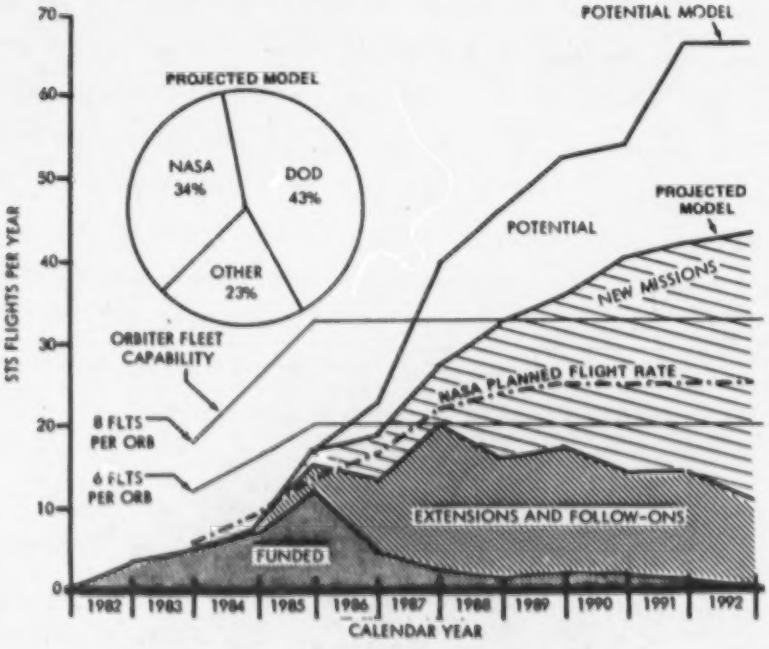

FIGURE 2

For demand projection purposes, payloads are grouped into four categories: (1) The government-funded missions which have a very high probability of launch and are typically well defined and in production, examples are the Space Telescope and Galileo missions. (2) Extensions and follow-on government missions which can be considered highly probable, but have not yet been included in the budgeting process. These include replacements for existing systems, Global Positioning System Block II satellites, and revisits to the Space Telescope. (3) New missions that have a reasonable probability of occurrence which are dependent either on the use of the Shuttle for new products or services, or more effective ways of accomplishing existing missions. (4) Those missions involving payloads (termed "potential missions") that show large potential benefits, some of which may be developed, but with less certainty and definition compared to the other categories. NASA has attempted to account for program slippages, cancellations and reductions in scope in its planned flight rate.

The cumulative funded, extension, follow-on, and new missions (in terms of equivalent STS flights per year) have been further grouped together to derive the projected model shown on the Figure 2.

The current NASA Space Shuttle planned flight rate (also shown on figure 2) through 1986 tracks very closely to the projected graph.

Beyond 1986, the non-U.S. Government launch demand is impacted by a number of variables, including the uncertainty of actual commitment to launch future systems which, at present, are in the planning stages.

Growth in demand could come from a number of sources. As an example, the Federal Communications Commission has recently approved the licensing of Direct Broadcast Satellites (DBS) which would increase the new mission and potential mission launch traffic categories. In addition, the FCC has requests for satellite-based paging systems. With the successful continuous flow electrophoresis system (CFES) experiment on STS-4, and subsequent flights, MDAC/Johnson & Johnson are actively planning a commercial pharmaceutical material-processing-in-space venture-estimated at a much higher level than in the projected flight model. (Such systems have not been included in the nomimal projection.) The video-conferencing business (both nationally and internationally) potential growth area as reflected by actual and planned expenditures in space systems and ground facilities.

A key variable in the U.S. Government demand is the extent to which the DOD's forecast of launch requirements will materialize. In the near term, the DOD launch model has tended to be overstated due to delays in payload fabrication schedules and the presence of call-up missions which will not be flown if operational systems already in orbit continue to operate satisfactorily. For the longer term, the DOD model does not reflect any expansion of space activities which may derive from the current National Space Policy.

The NASA contribution to the near-term flight planning is relatively firm, although some launches (such as Space Telescope) may experience some movement from one year to the next. In the longer term, the preponderance of NASA missions are tied in with the increasing usage of the Spacelab and other experiment carriers to fulfill NASA R&D objectives. A major variable here is the question of adequate financial support in future NASA budgets to develop and fly the planned complement of Spacelab and other missions. In summary, in the next thirty-six months period, there is a basis for believing that adequate projections have been made of the Shuttle launch demand for scientific and defense related requirements, and the commercial communication

requirements. The area of uncertainty will be the other industrial and commercial launch experiments and new government missions (such as Space Station and new DOD missions). The early years of Shuttle operational experience should confirm the assessment of launch rate capability.

C. Launch Assurance

Schedule reliability is a primary concern of all domestic, commercial, foreign and U.S. Government customers. Schedule reliability for the STS, the capability to establish and meet pre-established launch dates, involves a number of considerations: sufficient spares to repair/replace failed hardware; turnaround times with reasonable margins to accommodate routine problems; hardware deliveries which meet launch site need dates; sufficient flexibility to address requirements for reflights in the event of a mission abort or spacecraft failure; and, avoidance of single-point failures in both space and ground systems.

With respect to the orbiters, a major long-term factor in providing appropriate levels of launch assurance is the ability to withstand; the loss from service of one or more orbiters due to unscheduled maintenance/repair requirements, mission-unique changes or longer mission-related preparation times, changes/upgradings of the orbiters, and problem-related investigations. From the point of view of overall affordability, it is impracticable to procure sufficient protection against all potential causes of orbiter downtime. However, NASA does recognize the need to protect against the extended loss of service of the orbiter fleet such as would occur if a structural element had to be repaired or replaced. In addition, subsystem spares are being procured in sufficient quantities to comply with the precept that the hardware elements most subject to periodic replacement should be capable of being easily changed out.

An analysis of the effects on NASA's ability to meet the mission model through 1989, if an orbiter was lost from service, is depicted in Figure 3. This analysis is based on the assumption that the turnaround times depicted in Figure 1 are achieved. This figure does not include the potential use of scheduled contingency for short periods of time. The variable in Figure 3 relates to the mission time assumption, where the dotted lines indicate the availability based on all flights being between 3 and 7 days in duration.

FIGURE 3. RESERVE CAPABILITY

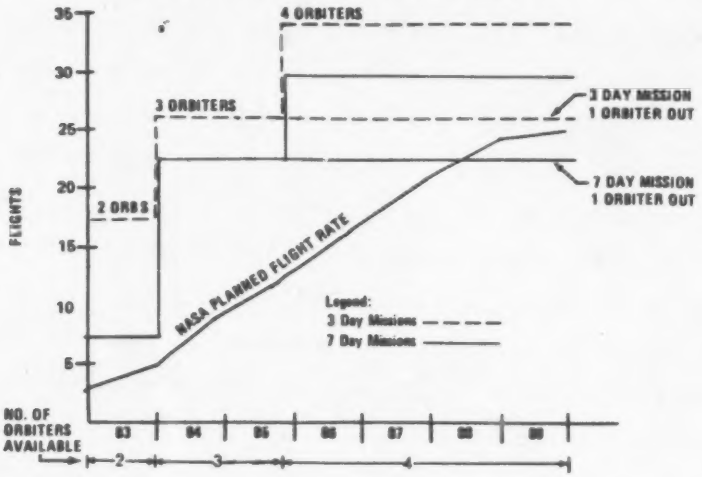

FIGURE 3

Based on this data, it appears that the present four orbiter fleet can meet the number of launches planned in the mission model during the rest of this decade even if an orbiter were lost from service. (As noted previously, the planned mission model does not only represent a projection of firm missions, but includes a significant number of anticipated missions in the 1986-1989 period.) In the event that problems do arise due to a

loss of capability, failure to meet projected turnaround times, or special requirements for meeting Vandenberg launch requirements, the STS has the flexibility to overcome some of the problems by recombining payloads, re-prioritizing payloads and, for short periods, using contingency time to assure timely launch of the most critical payloads.

III. STRUCTURAL SPARES/MAINTENANCE OF CAPABILITY

The FY 1984 budget includes $100 million (and $420 million in total runout) for the procurement of structural spares. While these spares are being specifically procured for the purpose of providing the necessary assurance that Shuttle operations will continue in the face of damage to structural elements, modifications, or other periods of extended orbiter outages, another important benefit to procuring the structural spares is the protection of our orbiter production capability. Following the delivery of the OV-104 hardware, many structural and component subcontractors would otherwise be closing down their orbiter lines; this action preserves major areas of production capability through late 1985 and early 1986, depending on the element.

The loss of the subcontractor base and the loss of production capability are key factors in determining the schedule, time, and cost of procuring one or more additional orbiters. This is due to the effects that the loss of skilled manpower, disinterest on the part of minor subcontractors (in bidding on small production buy quantities and consequently new vendor qualification), and loss of manufacturing facility equipment and site availability have on cost and schedules.

An examination of the subcontractor base erosion indicated it would have been most severe in the major structural areas. This is primarily because the normal logistical spares program being pursued focuses on non-structural black box and system level spares. Therefore, these non-structural subcontractors will have a spares fabrication program that will retain much of their capability through 1985 and into 1986.

It is apparent that a similar spares program for the major structural areas will have a similar effect on those subcontractors. Components produced under this approach will be used as spares to the four orbiter fleet or as elements for a fifth orbiter, if at some later time, a decision is made to proceed with this procurement. By having these structural spares

available, the impact of major damage to a fleet orbiter will be reduced. In addition, the initial effort to produce a replacement orbiter will be lessened by the availability of these components. If these components were used for a replacement orbiter an additional set of structural spares would possibly be procured.

Figures 4 & 5 depict how the production capability of two typical major structural subcontractors has been retained to some degree by this approach. Figure 6 is a representation depicting examples of the type of structural spares being procured along with their scheduled flow at the tail-end of the OV-104 activity.

FIGURE 4. MANUFACTURING CAPABILITY RETENTION

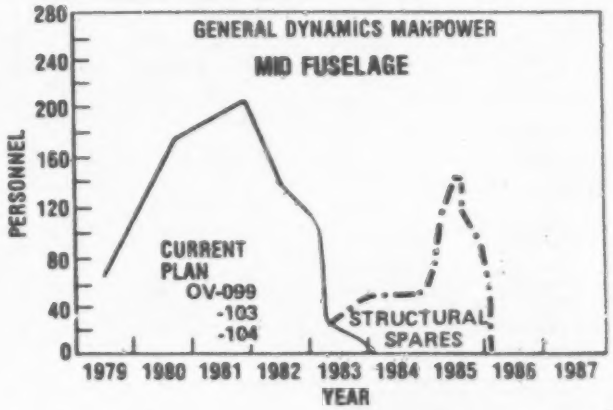

FIGURE 4

FIGURE 5. MANUFACTURING CAPABILITY RETENTION

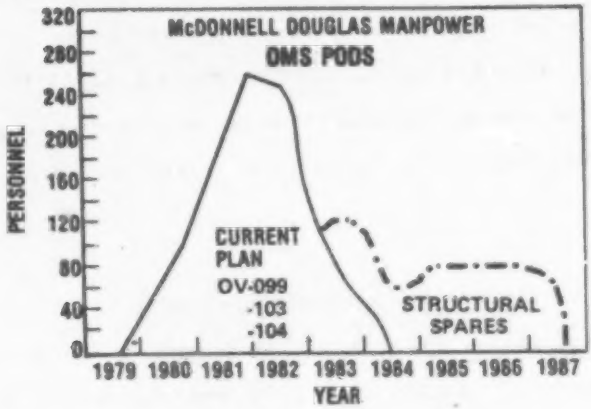

FIGURE 5

FIGURE 6. STRUCTURAL SPARES PROGRAM

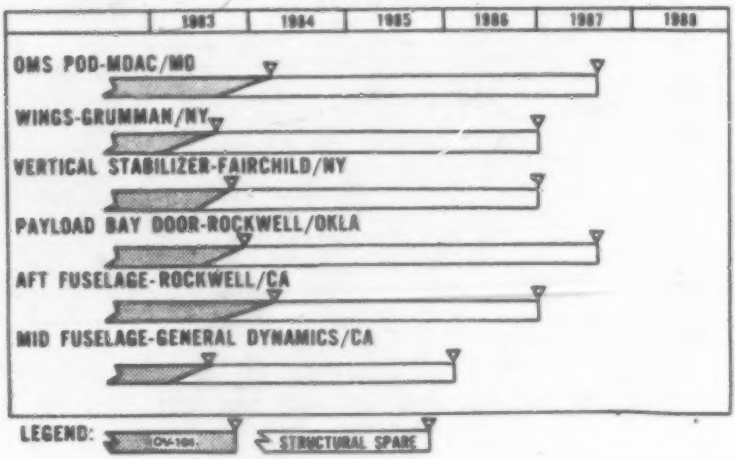

FIGURE 6

IV. COST CONSIDERATIONS

From the standpoint of operational costs, the costs of flying the Space Transportation System on a per flight basis are significantly reduced as the utilization of the inherent capability of the flight and ground hardware/manpower systems is optimized. As the launch rate is increased, the fixed costs are spread over a larger base. However, lower apparent average costs per flight do not necessarily mean lower total federal costs. This is influenced by the government/commercial ratio and the amount of customer reimbursements. From the standpoint of total federal investment costs and operational costs, there is a tradeoff that has to be made when a major investment in one area is made (such as procuring additional orbiters). That tradeoff must assure that maximum utilization is made of the investment in other areas and that flight rate operational economies will be realized. Among the considerations involved is whether the U.S. government should purchase additional Shuttle capacity to meet the needs of non-U.S. government users and the pricing policy in effect at that time. Other considerations may be involved, such as national security mission requirements, national prestige, cost economies made possible by fully utilizing the Shuttle's capabilities or ancillary economic benefits to the U.S. and its spacecraft industry associated with maintaining a dominant

position in launch service vis a vis domestic and foreign competitors.)

Assuming that the factors which are involved in deciding to procure one or more additional orbiters point to the need for adding on to the existing four orbiter fleet, the cost of that procurement is specifically influenced by the timing of the procurement, the number of vehicles being procured, and the concurrency of the vehicle build.

A. Procurement Timing

The sensitivity of the timing of a follow-on orbiter procurement to the cost of that procurement is well understood. Gaps which occur in production lines translate into the loss of skilled personnel with experience in building components and assembling them into major orbiter elements. If protracted, these gaps also involve considerations of the storing of tooling, the aging and obsolescence of equipment, and the restoration of factory floor space so that the space can be used for other purposes. The quality of the manufactured parts when manufacturing is resumed usually suffers for a period of time from the loss of trained personnel (both hands-on and supervisory) thus creating additional effort to obtain NASA required quality. Cost and schedule impacts are therefore common when such gaps occur. (See Figure 7).

FIGURE 7. GAPPING PENALTY

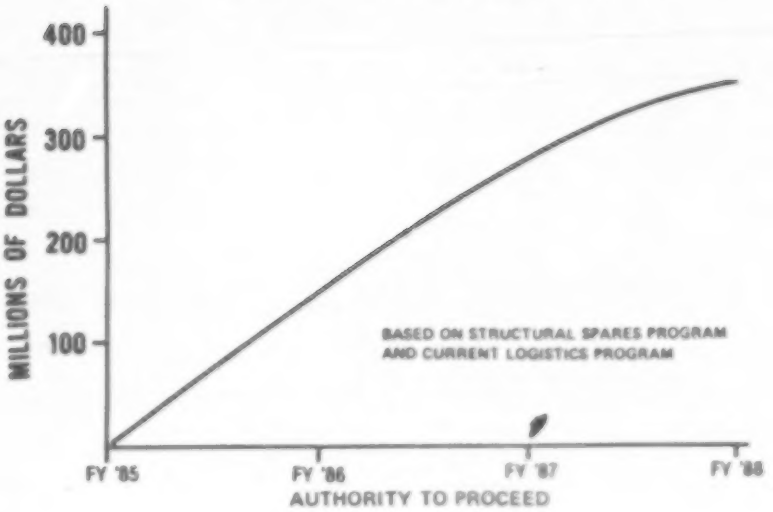

FIGURE 7

At present, Rockwell International's division responsible for the manufacturing of much of the orbiter is completing the final assembly and checkout of the third flight orbiter at its Palmdale, CA. facility. The build-up of the crew module, aft module, and forward reaction control modules for the fourth

flight orbiter is proceeding at the Downey, CA., plant, and will be delivered to Palmdale in late 1983 and early 1984. Due to the leadtimes involved in manufacturing additional orbiters, even an immediate start on a new orbiter would entail the loss of some of the skilled workforce at those two facilities. The suppliers and major and minor subcontractors to Rockwell are in various stages of completion of their work, depending upon whether spares are being procured from them to support the operational flight program or whether they are completing their deliveries in support of the fourth flight orbiter.

FIGURE 8, FOLLOW-ON PRODUCTION OPTIONS

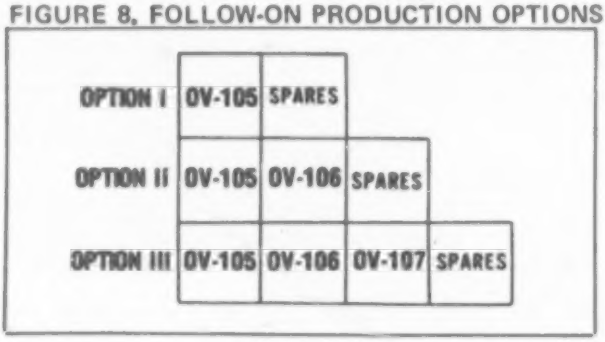

FIGURE 8

The FY 1984 budget, recommended by the Administration and approved by the Congress, provides for the retention of many elements of the orbiter production capability which were most susceptible to the effects of a gap in the production base. This capability retention will have the most effect on the major subcontractors building structural elements and to a more limited degree on the Rockwell in-house workforce. The major funding of $100 million for this effort was initiated in FY 1984, although $20 million was made available in FY 1983 to start work. Without authorization of this funding, most of the critical subcontractors who are involved in the orbiter structual fabrication would have closed down their production capability in 1983.

B. Lead-Time Away Procurement

This style of procurement has been used to fabricate the currently authorized four orbiter fleet. Simply expressed, it avoids the use of concurrent builds of identical structures and subassemblies and the early delivery of parts from vendors, and instead plans on initiation of work on the various elements so that the work is completed when the part is needed for the next level of assembly. This approach was used for OV-099, OV-103, and OV-104 by NASA to avoid the higher near-term funding requirements which would have been necessary had the builds for these orbiters been more concurrent. Concurrent builds

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of hardware take advantage of the efficiencies incurred by single tooling set-up and tear-down operations and by compressing the total build schedules. This approach has usually been less costly by a considerable degree over lead-time away scheduling. It is important to understand, however, that this distinction only holds true if the configurations of the two parts already built are identical and if there are no design problems which would force changes to the parts already fabricated. In the case of the four-orbiter fleet, there have been a large number of improvements made in the first three orbiters in an incremental fashion, and only the fourth orbiter has the same configuration as the third.

There is a general agreement that the current orbiter design (the OV-103/OV-104 baseline) will be used for building future orbiters and the structural spares, although there will likely be some exceptions to this if operational experience with the orbiters so indicates. The cost analysis provided below (in section D) indicates the probable difference in cost between a lead-time away procurement and a block buy procurement of a fifth and sixth orbiters as analyzed in 1982 and assumes no major changes or upgrades.

C. Block Buy Procurement

In 1982, NASA had examined a block buy approach in a future Orbiter procurement as a means to reduce overall production costs. Figure 8 depicts the various Orbiter production programs that would be ongoing if the decision to procure additional Orbiters was made. The emphasis had been on Option I which would include a block buy of OV-105 and a shipset of spares.

A block buy approach on OV-099, 103 and 104 was not feasible due to schedule and funding constraints and the lack of design qualification maturity. With the authorization to proceed with Structural Spares which could later be used for OV-105, the capability to block buy was lost. The ability to block buy is based upon release of contracts for multiple unit procurement. Analysis reveals that the first opportunity for block buy would be for OV-106 and OV-107. While block buys are normally used in large production runs where costs advantages can be achieved due to repetitive processes and larger lot runs, it is believed that the block buy concept can also be applied to any future multi-Orbiter procurement. Block buys for future Orbiter procurements will result in savings from techniques such as the following:

- o Quantity buys of materials and parts.
- o Capitalize on equipment which produce parts simultaneously.
- o Reduction in machine set-ups.
- o Shared support costs.
- o One set of planning documents.
- o Earlier completion thereby reducing inflationary impacts.
- o Prevention of loss of subcontractors and vendors.
- o Retention of critical skills.
- o Elimination of gapping penalties.
- o Rate reductions due to larger annual business volumes.

To assess the general feasibility of production savings with a block buy, NASA representatives visited the prime contractor, Rockwell International (RI), and three major subcontractors: General Dynamics, TRW and McDonnell Douglas. This assessment indicated that a block buy for future Orbiters was practical and could lead to significant cost savings. To analyze the specifics of the block buy concept, NASA requested that Rockwell International submit a budget and planning document in June, 1982 with a firm proposal for OV-105 in November 1982. These documents have been received and are discussed in detail in the following section. At the same time, NASA formed an in-house independent assessment team in order to make its own projections and to better understand the contractor's inputs.

D. NASA and Contractor Estimates

In 1982, Cost estimates were calculated by the contractor and an independent NASA assessment team. Several procurement options were evaluated. First was a stand alone OV-105, second an OV-105 plus a set of Line Replaceable Units (LRU's) for spares and third, a block buy of OV-105, OV-106 and a set of LRU's. Multiple schedule options resulted from exercises which attempted to smooth manpower requirements at the prime and/or subcontractors. Cost studies were made of both leadtime away and block buy procurement plans.

The NASA independent assessment team completed an initial study which addressed five cases. In each case the critical schedule path was the manufacturing of the aft fuselage thrust structure. Expected elapsed time from thrust structure material order authorization to vehicle delivery is approximately 5 years. The maximum schedule assumed a long lead item authorization in January 1983 and constrained funding in fiscal years 1983 and 1984. This schedule resulted in a mid to late 1987 Orbiter 105 delivery. Engine deliveries were assumed to be on five month centers from the current production and will support the delivery schedule.

The contractor submitted a budget and planning letter which presented preliminary estimates of the previously mentioned options and is presented in detail in Appendix D. A firm proposal was submitted in November 1982. The following matrix presents a comparison of the leadtime away and block buy Orbiter procurement plans. It does not include a set of LRU's. NASA's independent assessment team's estimate was within 3 percent of these total orbiter estimates.

CONTRACTOR'S
COMPARISON FOR OV-105, OV-106
LEADTIME AWAY VS. BLOCK BUY
REAL YEAR DOLLARS

FY	'83	'84	'85	'86	'87	'88	'89	TOTAL
Leadtime Away (Del. 9/87,12/88)	171	522	732	767	544	254	45	3035
Block Buy (Del. 9/87,12/88)	217	615	697	555	434	235	45	2798

The contractor's block buy showed a $237 million savings over the leadtime away estimates.

In summary, NASA performed an independent cost estimate for purchase of additional Orbiters and spares which is in general agreement with the contractor's Budget and Planning estimate contained in this report.

IV. POTENTIAL FUNDING STRATEGIES

A. Government Funding

The current Administration position is that the $420 million program of structural spares procurements provides for the retention of the major elements of the orbiter production base for an additional two to three years. As indicated previously, the case for procuring an additional orbiter at this time can not be convincingly made. The Administration is committed to a continual review of the need for more than four orbiters as information becomes available which would indicate that additional orbiters are required.

B. Private Funding

The Space Trans Company (STC) submitted in 1982 an unsolicited offer to fund the production of an additional Orbiter.

The Space Trans Company proposed to purchase a Shuttle Orbiter in return for which they would serve as the contracting agent for the use of that Orbiter and be authorized to market the STS to all commercial and foreign users. Under the STC offer, NASA would agree to operate and maintain STC's vehicle and to provide all launch facilities and services at a "reasonable" cost to Space Trans Co. Also, NASA would agree to launch their vehicle a specific number of times per year and to provide launches for any excess commercial and foreign user traffic on NASA's four Orbiters.

At this time the STC offer has been withdrawn.

V. REDUCING CURRENT ORBITER PRODUCTION COSTS

Because of the advanced status of the production program and the few number of items remaining to be procured, we have concentrated our efforts on improvements and refinements of technical and management approaches rather than making major production changes. We have already taken several steps and are examining others. We have a major effort underway directed at combining several separate elements of the basic Orbiter contract into one larger element to lower overhead and support costs.

This will also lead to some consolidation of activities at JSC. Concurrently, we are looking at the possibility of restructuring the contract into one which contains incentives.

In the manufacturing processes, numerically controlled machines have been installed at the Rockwell Downey, CA. manufacturing facility to produce hardware more efficiently. The NASA and Rockwell Corporate investment for these machines is expected to result in a three for one reduction in machine time for the applicable parts in the current production program.

New products or materials that are being used to reduce production costs include advanced flexible reusable surface insulation (AFRSI) to replace all the white tiles which are now used on Columbia and Challenger. This insulation will be used on OV-103 and OV-104 extensively and is estimated to reduce production costs by approximately $4M on OV-104. Some limited AFRSI is already in use on OV-099's OMS pods. Additionally, a computer aided design/manufacturing system (CAD/CAM) was installed at Rockwell to expand the capabilities and interfaces between engineering and manufacturing. A ten-month evaluation has indicated that those operations converted to CAD/CAM have significantly exceeded the 2 to 1 time utilization factor needed to justify the system as cost beneficial. With further training

and experience, the final time/cost benefits should exceed 3 to 1 and will result in direct savings to future Orbiter Procurements.

We are also proceeding with plans to institute a design freeze on production hardware and tightening of change control procedures. Together, these steps are expected to contribute significantly to lower production costs.

With regard to productivity, Rockwell International Corporation has made a vigorous effort to improve performance/productivity indicators. NASA reviews these monthly. Basic work centers have established goals or norms for measurable products and support. Further, combined supervisor and worker actions in key locations have been successful in improving productivity in hours required per part, in quality performance and in engineering outputs.

These indicators of problem areas are addressed with additional resources and management involvement. The program management continues to seek and identify additional performance indicators to measure critical function and schedule interfaces.

Cost Assessments

To estimate the costs of procuring additional Orbiters, NASA organized a cost team comprised of Headquarters and field center personnel. This team was organized in May 1982 and made the attached presentation on June 23, 1982.

Additionally, NASA directed the prime contractor, Rockwell International, to submit a Budget and Planning estimate. This preliminary estimate is summarized and presented in this Appendix. The contractor will also submit a firm proposal in October, 1982.

Various Orbiter procurement options were evaluated. The options included a stand alone OV-105 procurement, a OV-105 and a block buy of LRU's, and an OV-105 and an OV-106 block buy.

In both estimates the schedule was driven by the fabrication and assembly of the aft thrust structure. This long lead item was estimated to take 30-33 months for fabrication and 30-32 months for assembly. These elements resulted in an achievable schedule of between 60 and 65 months total.

The independent assessment team used different assumptions but verified the relative accuracy of the contractor's estimate. The contractor's estimate is presented in detail.

A. Contractors Budget and Planning Analysis

In June 1982 the contractor submitted in June 1982 a preliminary budget and planning (B&P) cost analysis with a firm proposal to follow in October of 1982. The contractor's B&P addressed several options.

Option One - Includes Orbiter 105 and a ship set of spares.

Option Two - A stand alone Orbiter 105 which assumes no concurrent Orbiter 106 effort.

Option Three - Adds a ship set of spareable hardware including long lead structural material which would be used for Orbiter 106.

Option Four - Costs Orbiter 106 bought on as a block buy with Orbiter 105.

Option Five - Orbiter 106 bought on a lead time away with Orbiter 105. The delivery schedule assumed a January 1983 go-ahead which resulted in an OV-105 delivery date of September 1987 and an OV-106 delivery date of December 1988.

The following costs and funding matrix depicts the contractor's Budget and Planning analysis.

CONTRACTOR B&P ESTIMATE
RY $ MIL

FY	83	84	85	86	87	88	89	TOTAL
OPTION								
1	228	594	618	444	249	14	2	2149
2	169	442	432	329	173			1546
3	351	735	622	365	177			2250
4	68	201	288	236	260	234	45	1332
5	11	81	314	442	371	253	45	1517

The main difference in these two approaches is the subcontractors are "turned on" for multiple components in the front of the program. The funding in the first two years are increased however the last five years are reduced, by this method a $237 million savings is realized.

CONTRACTOR'S
COMPARISON FOR OV-105, OV-106
LEADTIME AWAY AND BLOCK BUY ESTIMATES
RY $MILLION

FY	83	84	85	86	87	88	89	TOTAL
Leadtime Away (Del. 9/87,12/88)	171	522	732	767	544	254	45	3035
Block Buy	217	615	697	555	434	235	45	2798

B. Independent Assessment Team

The assessment team's estimates included, in addition to the prime contracor's cost, GFE, GSE, Mission Kits and Engines. The team analyzed the following cases:

Case One - Kept the existing procurement schedule for Orbiter vehicles 103 and 104 and had a leadtime away schedule for delivery of OV-105 in December of 1987. This option resulted in the lowest funding requirement in fiscal year 1983 and 1984.

Case Two - Shortened the schedule by removing the estimates for material and parts delays. This resulted in a delivery schedule of June 1987. Case two also maintained the current production program with no modifications.

Case Three - Modified the current production program by slipping the Orbiter Vehicles 103 and 104 delivery schedules by three and twelve months respectively. This approach minimized the manpower gapping problems

between OV-104 and 105, smoothed the manpower loading at Palmdale in 1983, and therefore, reduced the manpower reduction penalties.

Case Four - Identical to Case one; however, OV-102 was not modified for operational capability until after delivery of OV-104. This case was analyzed for two reasons. One, it reduced the schedule risk, for delivery of OV-103 associated with the current OV-102 modification plan which returned OV-102 to Palmdale after the STS-5 flight, and secondly, modifying OV-102 after delivery of OV-104 reduced the Palmdale gapping penalties between delivery of OV-104 and OV-105.

Case Five - Identical to Case one with the modification of OV-102 after delivery of OV-103. This minimized the schedule risk for delivery of OV-103 and resulted in a seven month span between completion of OV-102 modification and delivery of OV-104.

An option to Case five added a nine month schedule slip to the delivery of OV-104. This option reduced the peak manpower requirement at Palmdale and also reduced the gapping between delivery of OV-104 and OV-105.

The independent assessment team cost predictions were based on the assumption that the configuration of OV-105 was the same as OV-104. The estimate also includes a nine percent annual escalation factor. The manufacturing manpower estimates at the prime contractor assumed a learning disruption factor on an 87 percent improvement curve. The disruption factor resulted in a $22 million penalty for the current schedule gap between the delivery of OV-104 and OV-105. Subcontractor gapping penalties were based on current production and spares delivery schedules. The team estimated the mission model effects of the various cases but did not include cost adjustments for the various mission

models. Whereas the estimate includes increased ground support equipment, government furnished equipment, mission kits and engines, the estimate does not include additional facilities at the launch and landing sites.

NASA believes the data bases which were used in the assessment team's analysis are sound and are based on past actual expenditures. The assessment team did not attempt an analysis of a block buy where additional savings would be realized. The data for the block buy analysis are not in the existing data base.

C. Anderson AB48 1
C. Alcnau AB48 1
R. G. Jones 007 CA0 1
H. Green 001 CS0 1
C. Jeffs 001 A12 1
W. Lake AC80 1
R. Lashbrook AA43 1
R. Leath AA41 1
R. Petrone AA50 1
R. Schwartz AA48 1
S. Weinberg AA82 1
D. Whitman AA56 1
D. Eichinger AA77 1
2C01 1
WFD
FORM 906-D REV. 8-71

June 29, 1982 In Reply Refer to S2MA3082

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Attention: E. E. Easley, BC4
Contracting Officer

Reference: (a) NASA letter BC42-82/146, dated May 5, 1982
(b) Rockwell wire MA2086, dated May 7, 1982
(c) NASA wire BC42-82/168, dated May 14, 1982

Contract NAS9-14000, Evaluation Data for Procurement of Orbiters 105 and 106

Submitted herewith is the Orbiter 105 and 106 evaluation data agreed upon in the referenced correspondence. This data follows the sequence shown in the reference (b) wire. Enclosures provide an expansion of the estimates contained in this letter.

A. The estimate to complete (ETC)(from May 1, 1982) all Increment 3 work authorized through March 1982 is $1,291M. This ETC includes the contractor's estimate to perform the OV-102 "Maxi-Mod" after STS-5. The estimate further assumes a six month schedule set-over of OV-104 (delivery June 1985). (A "Maxi-Mod" of 33 weeks and approximately $44M has been assumed for purposes of this ETC.) (See Enclosure A)

B. (1) The estimated target cost and target price for Orbiter 105 and the concurrent release of one ship set of sparable Orbiter 106 hardware (including long lead structural material) are $1,919M and $2,149M respectively. This estimate is based upon a CPIF contract arrangement and the ability to "block buy" the OV-106 ship set of hardware along with OV-105. A January 1983 NASA go ahead was assumed which would result in an OV-105 delivery date of September 1987. (See Enclosure B-1)

(2) The estimated target cost and target price for Orbiter 105 only are $1,381M and $1,546M respectively. This estimate is based upon a CPIF contract arrangement and a delivery date of September 1987. (See Enclosure B-2)

C. The estimated target cost and target price of one additional ship set of sparable Orbiter hardware are $630M and $705M respectively. This estimate is based upon a CPIF contract arrangement and a January 1983 NASA go ahead. (See Enclosure C)

D. The estimated target cost and target price for Orbiter 106 are $1,189M and $1,332M respectively. This estimate is based upon a CPIF contract arrangement and the release of OV-106 on a "block buy" basis along with OV-105, and a OV-106 delivery date of December 1988. If OV-106 were to be authorized separately and procured on a "lead time away" basis from the December 1988 delivery date, the target cost and target price would then be $1,355M and $1,518M. The "block buy" approach yields a total cost saving of $238M when combined with the additional savings which would be realized on Orbiter 105. (See Enclosure D)

E. NASA authorization of Orbiter 105 by January 1983 yields a potential $151M cost saving/avoidance to the existing Increment 3 work. This saving is based upon the ability to achieve such economies as the deferral of the need for operational hardware maintenance support, both in-house and at subcontractors, as well as shared support costs and overhead rate effects.

F. In order to maximize the economic benefit of "block buying" Orbiter 105 and 106 vehicle hardware, NASA authorization for a complete Orbiter 105 and 106 long lead structural material should be received by January 1, 1983. To maintain this saving, full go ahead for Orbiter 106 should be received by January 1, 1984. The potential termination liability (PTL) for this long lead structural material by January 1, 1984 is $22M. If Orbiter 106 is not authorized, a high percentage of this material could be transferred to other programs or returned to suppliers for a minor restocking fee. It is estimated that these actions could reduce the resulting liability to $6M - $8M.

The significant assumptions upon which these estimates have been developed are outlined below and in the enclosures to this letter.

SCHEDULE: Enclosure E is the hardware schedule utilized in preparing this estimate.

CONTRACT TERMS: In general, Schedule Articles and General Provisions similar to those contained in Schedule B of the contract have been assumed, with appropriate modifications for a CPIF arrangement. Such areas as the interrelationship of this new work with on-going production work, including an identification of authorized changes included, will be included in the Contractor's October Firm Price Proposal.

HARDWARE DEFINITION: Hardware will be delivered to a Part II Contract End Item specification which will define both a deliverable configuration and specific acceptance test requirements. The specified configuration will be that of OV-104.

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FEE STRUCTURE: For budgetary and planning purposes a target fee of 12% has been used in these estimates. The complete CPIF structure to be presented with the firm price proposal in October will also contain a fee rate in excess of the limitation contained in Paragraph 3.405-4(c) of the NASA Procurement Regulations.

FACILITIES: Estimates are based upon the availability of the same facility arrangements as are currently in use on Schedule B. Use of Buildings 295 and 296 (or suitable replacements to be furnished by NASA) at Palmdale was assumed and no impact was included for the contingency that these buildings would not be available. No impact to the above ETC (or to Orbiter 105 estimates) has been included to reflect any of the options for resolving this facility situation during the Schedule B Program timeframe. Additionally, no costs were included for repair/rehabilitating Government facilities at contractor sites.

The Contractor's estimates for the above work are provided for budgetary and planning purposes. The Orbiter 105 estimate of $1,495M (included in the paragraph B-1 estimate above) represents the high end of a range of estimates that could, depending upon receipt and evaluation of subcontractor firm proposals, be reduced to $1,250M. The Contractor is proceeding with the preparation of a firm price proposal, for submittal in October 1982, covering the addition of Orbiter 105 and one additional ship set of sparable hardware and long lead structural material for Orbiter 106. The Contractor strongly urges the NASA to authorize long lead structural material for Orbiters 105 and 106 this summer, prior to the full vehicle go-ahead anticipated in January 1983. Schedule requirements for these items are critical to minimizing overall program costs and achieving the desired end item delivery dates. The Contractor is prepared to review the cost and schedule data compiled in developing these estimates with you at your earliest convenience.

ROCKWELL INTERNATIONAL
Shuttle Orbiter Division

R. Schwartz
Vice President & General Manager

TS:sc

Enclosures: A: Estimate to Complete Increment 3
B-1: OV-105 and Sparable Hardware
B-2: Orbiter 105 Stand Alone
C: One Additional Shipset of Sparable Hardware
D: OV-106 Estimates
E: Hardware Schedule (Proposed Only)

cc: A. Cohen, MA, NASA/JSC, Houston, TX (w/enc)
T. R. K[illegible]es, MC, NASA/JSC, Houston, TX (w/enc)
L. W. Bethers, BC121, NASA/Downey, CA (3)(w/enc)
D. D. Ewart, MR12, NASA/Downey, CA (w/enc)
W. B. Wilson, MR, NASA/SSPRO, Downey, CA (7) (w/1 copy enc)
J. Davison, ME, NASA/QAR&S, Downey, CA (w/enc)
Addressee (3) (w/enc)

Enclosure (A) to
Letter 82MA3082

ESTIMATE TO COMPLETE INCREMENT 3

Basis for Estimate

1. Includes OV-102 Maxi-Mod incorporation after STS-5 (based upon 33 weeks and approximately $44M).
2. Enclosure E Schedule
3. All authorized work through March 1982
4. ETC from May 1, 1982 through June 1985.

(Dollars in Millions)

	FY 82	FY 83	FY 84	FY 85	TOTAL
Engineering	29.7	45.8	24.5	13.5	113.5
Production Oper.	76.0	210.6	117.7	67.2	471.5
Material*	149.3	233.9	24.8	0	408.0
Quality Assur Business Mgt)	22.3	50.0	35.9	19.2	127.4
Logistics)	16.6	35.9	27.6	12.7	92.8
Subcontract Mgt)					
Other	(3.4)	(2.6)	(.7)	0	(6.7)
Total Cost	290.5	573.6	229.8	112.6	1206.5
Fee	22.1	37.0	17.0	8.4	84.5
Total Price	312.6	610.6	246.8	121.0	1291.0

*Including IDWA

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Enclosure (3-A) to
Letter 82MA3082

ORBITER 105 & SPARABLE HARDWARE

Basis for Estimate

1. Enclosure 2 Schedule
2. NASA authorization by January 1983.
3. Orbiter 105 end item delivery by September 1987.
4. Hardware configuration same as Orbiter 104 including changes authorized through March 1982.
5. Sparable hardware estimate based upon long lead structures plus one ship set of sparable hardware.

Summary By Category (Dollars in Millions)

Block Buy	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	TOTAL
OV-105	163.8	417.7	414.5	326.0	173.0			1495.0
Sparable Hardware	52.4	163.9	198.4	117.9	75.9	14.0	1.8	624.3
L/L Struct Assy's	12.1	12.4	5.5					30.0
Total Price	228.3	594.0	618.4	443.9	248.9	14.0	1.8	2149.3

Summary by Function (Dollars in Millions)

	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	TOTAL
Engineering	9.1	28.4	41.7	40.9	25.5	.7		146.3
Production Oper.	7.3	30.6	80.2	118.4	86.5	3.0	.1	326.1
Material*	181.6	449.4	375.0	165.6	49.9	4.6		1226.1
Quality Assur	1.2	5.5	24.1	42.2	33.2	.6		106.8
Business Mgt) Logistics) Subcontract Mgt)	4.6	16.4	31.1	29.3	27.2	3.6	1.5	113.7
Total Cost	203.8	530.3	552.1	396.4	222.3	12.5	1.6	1919.0
Fee 12%	24.5	63.7	66.3	47.5	26.6	1.5	.2	230.3
Total Price	228.3	594.0	618.4	443.9	248.9	14.0	1.8	2149.3

*Including IDMA

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Enclosure (B-2) to
Letter 82MA3082

ORBITER 105
STAND ALONE

1. Enclosure E Schedule

2. Full go-ahead by January 1983

3. Orbiter 105 end item delivery by September 1987.

4. Hardware configuration same as Orbiter 104 including changes authorized through March 1982.

5. Assumes no concurrent Orbiter 106 effort.

(Dollars in Millions)

	FY 83	FY 84	FY 85	FY 86	FY 87	TOTAL
Engineering	7.2	22.6	34.3	36.4	22.7	123.2
Production Oper.	7.3	29.6	73.0	113.5	82.1	305.5
Material*	129.2	322.3	236.1	80.8	0	768.4
Quality Assur	1.2	5.3	22.7	41.2	32.3	102.7
Business Mgt) Logistics) Subcontract Mgt)	6.0	15.2	20.7	21.5	17.4	80.8
Total Cost	150.9	395.0	386.8	293.4	154.5	1380.6
Fee 12%	18.1	47.4	46.4	35.2	18.5	165.6
Total Price	169.0	442.4	432.2	328.6	173.0	1546.2

*Including IDWA

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Enclosure (C) to
Letter 82MA3082

ONE ADDITIONAL
SHIPSET OF SPARABLE HARDWARE

Basis for Estimate

1. January 1983 authorization to proceed.

(Dollars in Millions)

	FY 83	FY 84	FY 85	FY 86	FY 87	TOTAL
Engineering	6.3	10.5	7.6	1.9	.4	26.7
Production Oper.		3.8	10.6	8.3	2.6	25.3
Material[a]	150.8	235.6	138.3	14.9		539.6
Quality Assur		.9	2.1	2.2	.5	5.7
Business Mgt)						
Logistics)	5.5	10.9	10.9	5.2	0	32.5
Subcontract Mgt)						
Total Cost	162.6	261.7	169.5	32.5	3.5	629.8
Fee 12%	19.5	31.4	20.3	3.9	.4	75.5
Total Price	182.1	293.1	189.8	36.4	3.9	705.3

[a]Including IDMA

Enclosure (D) to
Letter 82MA3082
Page 1 of 2

OV-106 ON A BLOCK BUY
WITH OV-105

(Dollars in Millions)

	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	TOTAL
Engineering		.7	3.5	17.1	33.4	34.4	5.3	94.4
Production Oper.			35.2	43.9	76.5	111.6	20.3	290.9
Material*	58.4	172.1	200.4	126.6	82.8	4.2	0	644.5
Quality Assur	0	.7	5.4	8.5	22.2	36.3	6.3	79.4
Business Mgt)								
Logistics)	2.1	2.2	12.3	14.8	17.6	22.8	8.2	80.0
Subcontract Mgt)								
Total Cost	60.5	179.1	256.8	210.9	232.5	209.3	40.1	1189.2
Fee 12%	7.3	21.5	30.8	25.3	27.9	25.1	4.8	142.7
Total Price	67.8	200.6	287.6	236.2	260.4	234.4	44.9	1331.9

OV-106 ON A LEADTIME AWAY BASIS
WITH OV-105

	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	TOTAL
Engineering		.7	3.5	17.1	33.4	34.4	5.3	94.4
Production Oper.			23.0	61.6	92.6	114.1	20.5	311.8
Material*	9.4	71.3	239.6	283.5	160.3	17.9	0	782.5
Quality Assur	0	0	3.4	11.4	24.9	37.1	6.4	83.2
Business Mgt)								
Logistics)	.5	.7	10.6	21.1	19.9	22.8	8.2	83.8
Subcontract Mgt)								
Total Cost	9.9	72.7	280.1	394.7	331.1	226.3	40.4	1355.2
Fee 12%	1.2	8.7	33.6	47.4	39.7	27.1	4.9	162.6
Total Price	11.1	81.4	313.7	442.1	370.8	253.4	45.3	1517.8

*Including IDMA

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Enclosure (D) to
Letter 82MA3082
Page 2 of 2

SPACE SHUTTLE PROGRAM - ORBITER PROJECT
OV-105/OV-106 PROCUREMENT

(Dollars in Millions at Price)

Lead Time Away	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	TOTAL
OV-105	159.9	440.6	418.6	325.1	173.0			1517.2
OV-106	11.1	81.4	313.7	442.1	370.8	253.4	45.3	1517.8
TOTAL	171.0	522.0	732.3	767.2	543.8	253.4	45.3	3035.0
Block Buy								
OV-105	149.3	414.7	409.5	319.1	173.0			1465.6
OV-106	67.8	200.6	287.6	236.2	260.4	234.4	44.9	1331.9
Total	217.1	615.3	697.1	555.3	433.4	234.4	44.9	2797.5
Estimated Savings	46.1	93.3	(35.2)	(211.9)	(110.4)	(19.0)	(.4)	(237.5)

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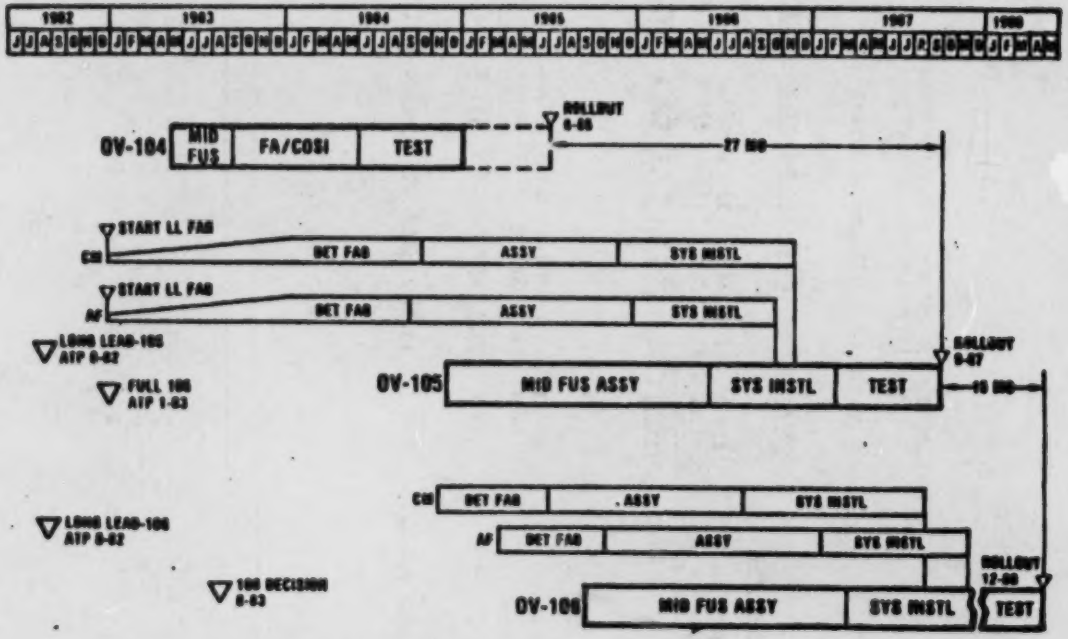
ORBITER 105/106



APPENDIX A: Contractor's Budget and Planning Letter Estimates for Procurement of Additional Orbiters.

NOTE: The following data reflect early to mid 1982 and do not reflect the impact of the current structural spares procurement.

APPENDIX 3

NASA
National Aeronautics and
Space Administration

AEROSPACE SAFETY ADVISORY PANEL

ANNUAL REPORT

COVERING CALENDAR YEAR 1983

JANUARY 1984

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DEDICATION

The Aerospace Safety Advisory Panel wishes to express its thanks for the contribution to this annual report by Robert D. Rothi. Bob was a consultant to and a member of the Panel from August 16, 1982 to his untimely death November 27, 1983.

All of us came to know Bob as a friend, a colleague, and a sincere, intelligent, practitioner of the engineering art. We remember him as he would have wished, with pleasure rather than sorrow, and extend to his family our sympathy as well as our gratitude for having known him.

NASA AEROSPACE SAFETY ADVISORY PANEL

ANNUAL REPORT COVERING ACTIVITIES FOR CALENDAR YEAR 1983

JANUARY 1984

INTRODUCTION

The NASA Aerospace Safety Advisory Panel has completed its assessment of NASA's safety performance for 1983 and affirms that NASA Headquarters and Center management teams continue to hold the safety of manned flight to be their prime concern, and that essential effort and resources are allocated for maintaining safety in all of the development and operational programs. The Aerospace Safety Advisory Panel continues to have access to NASA management at all levels and has found no difficulty in obtaining available data from any of NASA's policy, development, test or operational activities to assist in the evaluation of safety performance.

During 1983, NASA programs for the operational use of the Space Transportation System and their continuing use of aircraft for training, experimentation, and administrative service demanded the largest share of the Aerospace Safety Advisory Panel's attention, and this report addresses those problems which the Aerospace Safety Advisory Panel believes are in need of focused attention.

In this report, the Panel has listed those conclusions most worthy of NASA management concentration along with our recommendations for action. Following these broad conclusions and recommendations are two sections one of which is a review and closeout of NASA's response to the 1982 Aerospace Safety Advisory Panel suggestions and the other of which offers comments on some broad NASA activities which have had and probably will have an impact on the safety of future systems and their operation. Finally, since the Aerospace Safety Advisory Panel conclusions have been derived from substantial detail investigations of the hardware itself, its testing, and its use, an appendix has been added which includes information on Panel studies and reviews which have contributed to the primary conclusions.

It should be recognized that the transition from R&D flying of the Space Transportation System to its operational use introduces many opportunities for management policies and actions to expedite the achievement of maximum safety. Thus, many of the Aerospace Safety Advisory Panel comments have to do with the management approach to operational status for the Space Transportation System. It appears that much needs to be done before the Space Transportation System can achieve the reliability necessary for safe, high rate, low cost operations.

CONCLUSIONS AND RECOMMENDATIONS

1. Product Quality and Utility

Conclusion: Although present quality assurance programs are thorough, and documentation extensive, the Panel believes that these conventional approaches could be augmented by more motivational emphasis in the development and production phases of hardware and software. The Panel believes that more emphasis should be placed at the contractor and subcontractor level on design suitability and production quality to complement the present quality assurance programs. This emphasis should include motivation of the entire Space Transportation System (STS) design team now addressing improvements to be certain that operational problems are alleviated through these design improvements and elements of the STS which are difficult to inspect, involve obsolete technology, or require frequent maintenance and replacement are changed.

Recommendation: NASA make a concerted effort to assist contractors and subcontractors to produce the highest quality of product, oriented toward operational suitability. NASA and contractor employees, both design and production, should now be approaching their work on subsequent hardware improvements with operational suitability rather than increased performance as the dominant goal.

2. Shuttle System Main Engine (SSME)

Conclusion: The current design of the SSME, with the exception of the turbomachinery, appears to be suitable, assuming satisfactory completion of the specified acceptance tests, for approximately seven flights at full power level (FPL), i.e., 109% of the original rated power level (RPL). The current high pressure turbopumps at this rating of 109% are, apparently, suitable for only one or two flights at 109% thrust before removal for teardown inspection and possible replacement is required.

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The Aerospace Safety Advisory Panel (ASAP) agrees with the prudent decision to limit the operation of these engines to the 104% thrust level as this mitigates but does not eliminate the problems of the engine turbomachines and provides operating margin. The engines have performed well during the 1983 flights at the 104% level confirming the wisdom of selecting this constraint.

The SSME project has adopted a three-phase program to develop a longer life expectancy for the engine. The Aerospace Safety Advisory Panel has reviewed this program and supports and commends this organized approach to SSME improvement.

Recommendation: The SSME program should proceed with full NASA support and resources to firm up the content and planning for SSME improvement and to implement the program and pursue the objectives vigorously. Retrofit of certified improvements during scheduled or unscheduled removals of the engines is firmly recommended. The plans should continue to include the activity on a full redesign of the high pressure turbomachines that was begun this year. The Aerospace Safety Advisory Panel believes this effort to be necessary to achieve the margin of safety required for routine operations and long life of the engine.

As testing to demonstrate margin for operation at the 109% level will involve operation at thrust levels higher than 109%, there will be temptation to increase the Shuttle performance by utilizing higher thrust. The ASAP advises strongly against such a decision. Operational reliability, and the concommitant safety can be achieved only by operating the engines at thrust levels below the maximum demonstrated in a few tests to show that a margin exists.

3. Landing Gear

Conclusion: In a number of previous reports and discussions, the ASAP has suggested that the landing gear on the Orbiter has not been

designed with enough structural and functional margin for repetitive use. The response to the suggestions contained in the 1982 report does not appear to the Panel to have answered the fundamental question of achieving sufficient margins for operational reliability and safety.

Recommendation: A complete structural and mechanical suitability review of the Shuttle landing gear be made by an engineering organization with commercial transport experience for the purpose of suggesting alternative landing gear configurations and setting target margins for structures and the wheels, brakes, and axles. This review should include but not be limited to:

a. The practicality of converting to a four-wheel main gear truck within the present wheel well.

b. The practicality of putting an extended or extendable strut on the nose gear for the purpose of changing the Orbiter ground attitude (more positive angle of attack), thus relieving the main gear roll-out loads.

c. The feasibility of increasing brake capacity by a major percentage (at least 25%).

d. A thorough review of the weak points on the present gear followed by suggestions for beef-up to bring the margins into partial comparability with the margins of modern transport aircraft in the landing mode.

4. Logistics and Maintenance

Conclusions: During 1983 the Aerospace Safety Advisory Panel has observed considerable progress in the areas of logistics, maintenance, supply and support programs intended to avoid launch delays due to material shortages. Suitable directives are being developed to encourage liaison between United States Air Force and National

Aeronautics and Space Administration through a co-ordinating group known as the Integrated Logistics Panel (ILP).

The Aerospace Safety Advisory Panel applauds the award of the Shuttle Processing Contract (SPC) in October 1983 but would welcome a clear definition of its role and responsibilities in the logistics field. Plans for transition of logistics and support activities from Marshall Space Flight Center and Johnson Space Center to Kennedy Space Center are in existence but are proceeding slowly and are not scheduled for completion until 1986.

There is no evidence of a long-term overall maintenance plan for the entire Shuttle system. Additionally, some doubt exists as to whom the ultimate responsibility for logistics really belongs and this is clouding the improving liaison between United States Air Force and National Aeronuatics and Space Administration. This may, in part, be due to the non-existence of a single top authority over combined USAF-NASA logistics. A stronger hand from NASA Headquarters in Washington would probably help. Both recommendations, that is, for the maintenance master plan and the appointment of a "czar" have been made previously by the Aerospace Safety Advisory Panel and valuable time is being lost during which some clarity and resolution could have been introduced into the entire logistics progam.

There appear to be some major voids in the logistics programs as presently envisaged. For example, no mandate exists for exploring the adequacy and suitability of logistics programs for Spacelab, Centaur, Inertial Upper Stage or Payload Assist Module systems.

The payloads can contribute to launch delays just as significantly as the Orbiter if logistical support is not considered as an entire system.

Recommendations:

a. A single authority be established responsible for all logistics systems.

b. An overall maintenance plan be established attempting to provide for at least the next decade.

c. The role of the Shuttle Processing Contractor in the vital sphere of logistics should be cleary defined as soon as possible.

d. Spacelab, Centaur, Inertial Upper Stage, and Payload Assist Module should be included in the logistics plans.

5. Orbiter Structural Loads

Conclusion: The most current structural loads for the Shuttle were derived in 1976/1977 and are called the ASKA 5.4 loads. The meager flight test data that has been acquired to date does not validate the ASKA 5.4 loads. To operate the Orbiter up to its safe strength with confidence, aerodynamic loads in ascent and thermal loads in descent need to be better defined.

Recommendation: The Aerospace Safety Advisory Panel recommends that National Aeronautics and Space Administration expedite the derivation of a new set of loads based on the latest wind tunnel and flight data. The Aerospace Safety Advisory Panel further recommends that renewed efforts be made to validate the final derived structural loads with full-scale flight data.

6. Orbiter Landing Speed and Pitch Control

Conclusion: Orbiter flights to date have demonstrated high landing speeds, landing gear loads near the design limits, many brake malfunctions, and a wide scatter in touchdown points.

Handling-quality tests on simulators have verified the sensitivity and inherent instability in pitch control that contribute to the Orbiter's problems.

Excessive landing speed and control sensitivity result in:

a. A continuing potential for a landing accident to occur
b. Limitations on choice of abort sites
c. Risk of destructive brake malfunctions
d. Non-survivable open sea ditchings
e. Lengthy and expensive training programs.

Program management apparently recognizes the above, as evidenced by a reluctance to use the Kennedy Space Center landing strip despite the logistic and turnaround advantages resulting from its use. The ASAP concludes that a major reduction in landing velocity, and an improvement in the apparent stability (and consistency) in pitch control near the touch down point, would substantially improve the operational flexibility and safety potential for the Orbiter.

Recommendation: NASA Headquarters should request Langley Research Center (LaRC) to review the "state of the art" in canard configured aircraft, and prepare briefings to the Aerospace Safety Advisory Panel and NASA Headquarters on the advantages and limitations of canard configurations as applied to the Orbiter. In parallel, Johnson Space Center (JSC) should be asked to explore the practical problems of installing controllable canards on the Orbiters for use in landing.

7. Shuttle Processing Contractor (SPC)

Conclusion: Although it is too early to reach any definitive judgments as to the operational effectiveness of the Shuttle Processing Contractor (SPC), Lockheed Space Operations Company, the planning, preparation, and initial actions during the transition period take account of concerns raised by the Panel in earlier reports. To date, Lockheed has been generally successful in hiring

key personnel of contractors which have been responsible for processing operations. It is important that this success rate be maintained among the contractors--Rockwell International, Martin Marietta, United Space Boosters--whose final transition dates occur after STS-11 in early 1984. In addition, National Aeronautics and Space Administration can assist the Shuttle Processing Contractor in carrying out its responsibilities through such actions as moving toward a unified logistics system, acquiring an adequate number of spares, defining major and minor overhaul sequences, developing coordinated launch schedules for Kennedy Space Center and Vandenberg Air Force Base, and consulting closely with the Shuttle Processing Contractor on major hardware acquisitions and enhancements that relate to Shuttle processing. The Aerospace Safety Advisory Panel will continue to monitor closely Lockheed's assumption of these critical processing responsibilities.

Recommendation: National Aeronautics and Space Administration should clarify as rapidly as possible its internal organizational arrangements that will support routine operation of the Space Transportation System. Such organizational clarity will be a major factor in achieving the objectives noted above and in assisting the SPC.

8. Safety of Flight Operations

Conclusions: Nineteen hundred and eighty-three was a significant year in the evolution of flight safety for the aircraft used at the National Aeronautics and Space Administration Centers. Flight safety has received considerable attention at the highest levels. The revitalization of the Intercenter Aircraft Operations Panel (IAOP) and the many constructive recommendations from the ECOsystems International Inc., and internal reviews should be effective in enhancing safety of flight operations. Still lacking are:

a. Effective communication both up and down the management chain, on flight safety matters, from Headquarters to the flight operations level at the centers

b. A "Director of Flight Operations" or the equivalent in NASA Headquarters

c. An appreciation at the Headquarters level of the role of human factors in aviation accidents

d. An update of Headquarters aircraft and flight operations policies and management instructions.

Recommendations: A "Director" or "Chief" of Flight Operations should be identified and should be the focal point of flight safety matters in NASA Headquarters.

This "Director" should serve as a channel of communication from the branch flight operations level at the Centers to whatever administrative level that is necessary to fully resolve a flight safety problem.

National Aeronautics and Space Administratation Headquarters through the "Chief of Flight Operations" and the Intercenter Aircraft Operations Panel should complement the supervision of flight operations with studies and educational programs aimed at the human factor problem in aviation accidents and assure that appropriate policy documents are issued by Headquarters to meet operational safety needs.

PROGRAM ASSESSMENT

Product Quality and Utility

Together National Aeronautics and Space Administration and the Aerospace Safety Advisory Panel have concerned themselves with the effectiveness of the "Product Quality Assurance Program" and its adequacy to support the safety performance of the manned space flight program. During the history of the STS development a body of procedures, reports and records has grown up that defines in detail the route to be followed in the manufacture of already designed hardware. The pattern developed does not always result in suitable hardware. Another product of the system has been a documented history that will allow later analysis to pinpoint the cause after failure has occurred. This paperwork system and its implementation is massive and hence costly but it is not clear that it directly affect hardware adequacy. In a recent review of quality assurance held at Marshall Space Flight Center covering contractors and subcontractors, hundreds of deviations from prescribed product assurance procedures were reviewed. In spite of these deviations, all contractors stated that there had been no hardware impact. Now that the hardware task is becoming more one of replacing and fixing, it is important to put emphasis on the development engineering needed to insure that equipment that has been found wanting either in suitability or life under operational conditions is properly designed for operation. The achievement of appropriate operational design and the motivation of workers to produce to that design are essential to make traditional quality assurance programs worth the cost.

The ASAP did not perceive sufficient emphasis on directing actual worker attention to those things that, in fact, affect the quality of the work to be done. There is no intention here to imply that the whole body of product quality assurance is not valuable but we believe that it should be complemented by more attention to operational engineering and to the production system itself to insure that each

piece of hardware produced is as near perfect as possible and that it is of an appropriate design for the operational era. Quality assurance does not make hardware--a worker does, and quality assurance is only one of his tools. It should be remembered that STS elements for the most part come from small production, not mass produced items which are susceptible to more automated quality controls. Product quality for such small production is basically a function of the producing organization not the quality assurance organization. Thus, a product of integrity demands:

- o Suitable design
- o Proper tools and instructions
- o Worker education
- o Worker motivation

The first of these factors is in a large part a result of the engineering which reflects experience and management dedication to operational utility. The second quality assurance factor is the provision of proper tools, fixtures, and jigs calibrated to the extent necessary. Inspection equipment should be available as necessary and all prints and procedures must be current and explicit. It might help if a given worker had only the paper of importance to his job. Large data packs all of which do not concern the individual worker tend to obsure the importance to him of the few pieces of paper relevant to his particular task.

The third factor, worker education, is more important than most people realize. The majority of the workers on NASA projects either in engineering or production are conscientious, qualified, and intelligent people who want to do a good job. Every effort must be made to acquaint them with the importance, use, and characteristics of the equipment they are working on and the critical parameters that must be controlled. For instance, in some cases cleanliness may be simply good housekeeping and in other cases, such as hardware exposed to propellants or oxygen, it may be absolutely vital. The worker should know why certain procedures are demanding if he is expected to

produce a perfect product. Astronauts make visits to production facilities and this certainly motivates people. It might also be in order to have some of NASA's key engineering personnel conduct in-plant seminars on specific equipment and specific qualities it must have to do its intended job.

Finally, worker motivation beginning with the engineer is a difficult but rewarding task. The proper communications and communicators serve both an educational and motivational purpose. Quality circles are a useful technique so long as they do not produce unauthorized or untested changes in hardware or procedures. Along another line the worker must not depend on the inspector for quality; the inspector must simply confirm the worker's performance. The worker determines the quality of the product and each worker must be carefully reminded of this time and time again.

A new factor in product quality now faces NASA design and production practitioners who must produce reliable replacement hardware--particularly electronic. The designs of most of the Shuttle components are at least 10 years old and as industry has progressed new developments and design concepts have produced better and more reliable products. This coupled with difficulty in the reproduction of older style units, suggests that design change may be essential in achieving functional reliability. The problem that this aging poses for the Shuttle is that NASA cannot allow changes in design or substitutions in components without requalification of the hardware and a very comprehensive consideration of the effects of the change. It would seem to be in order for the Centers to determine in advance the extent of obsolescence, cost versus reliability improvements, the "delta" qualification requirements necessary for such updated equipment and establish a prioritized plan for determining the equipment to be replaced by that containing more modern technology.

Flight Readiness Review Changes

The Panel feels that in light of experience the Flight Readiness Review (FRR) process could be restructured to save some resources and, importantly from a safety point of view, to place the FRR operational decisions in the operations organization.

Panel members have participated in the majority, if not all of the Flight Readiness Reviews either in person or through telecons. These reviews have historically involved senior NASA management, senior program managers, numerous contractor managers, and with the pre-FRR Center meetings, almost the entire Space Transportation System (STS) mid-management population of NASA and their contractors. This effort is costly not only in travel and time but from the standpoint that a large number of senior people will not be doing other urgent things. With time and experience such priorities should have changed. As the operation becomes more routine, safety is enhanced by organizational clarity and the motivation produced by more precise definition of responsibilities.

The Aerospace Safety Advisory Panel feels that it is time for the STS Flight Readiness Review process to be restructured. We suggest a format for the change only to stimulate discussion and accelerate decision. We feel that the Centers should continue to hold their "pre-FRR" meetings and generate a Center readiness position. This should identify current problems, new risks, changes in old risks and other factors affecting readiness. We further suggest that the decision responsibility for flight readiness be delegated to the designated Director for Shuttle Operations wherever NASA decides to locate him, at Kennedy Space Center, at Johnson Space Center or at NASA Headquarters, Washington, D.C. after consultation with the Center Directors. We feel that such change would be more effective in the majority of the operations and would improve the motivation and quality of the NASA organization and its contractors.

Shuttle Processing Contract (SPC)

NASA's decision to consolidate under a single contractor all ground processing and launch and landing services, including operation and maintenance of associated ground systems, is a major step in the direction of achieving a genuine operational space transportation system. The scope of the Shuttle Processing Contractor's (SPC) responsibility is broad, including the processing of individual STS elements (Orbiter vehicle including main engines, external tank, solid rocket boosters), integration of these elements in preparation for launch, performance of on-line cargo integration and interface validation, and operation and maintenance of facilities and equipment required for processing, launch, post-launch, landing and de-servicing of the Shuttle vehicle. The activities of twelve (12) contractors are being consolidated under the SPC.

In September 1983, NASA awarded the Shuttle Processing Contract to the Lockheed Space Operations Company. The Lockheed team also includes Grumman Technical Services, Inc., Morton-Thiokol, Inc., and Pan American World Services, Inc.

Assigned individuals from the Panel have monitored the activities leading to the selection of the Lockheed team and will continue to follow the contract's implementation. It is essential that the important objective of achieving a more cost-effective operation (an operational space transportation system) not be permitted to introduce unacceptable risks to the Shuttle crew or the vehicle system itself. In striving for this proper balance between desired cost-effectiveness and acceptable risk, there is the initial challenge of the SPC accepting and carrying out the many technically demanding responsibilities of twelve (12) separate contractors, many of whom were developers of the STS elements. There is also the longer-term challenge of maintaining rigorous attention to detail and quality when the STS operation becomes more routine, the flight rate increases, and cost-control pressures intensify. How the initial challenge of

transition is approached will more than likely lay the groundwork for solving the longer-term problems associated with truly routine operations.

Lockheed is presently going forward with transition plans to assume responsibility for the work performed by the previous contractors. To date, the transition is essentially on schedule with assumption of all responsibility at Kennedy Space Center (KSC) to be complete by February 6, 1984, following the launch of mission 41-B (STS-11). Lockheed will be totally responsible for the processing of mission 41-C (STS-13), scheduled for launch in April. At Vandenberg the transition will take significantly longer with initial operational capability scheduled for late 1985.

A critical factor in sustaining processing capability will be Lockheed's success in hiring the key personnel of other contractors. As of early December, Lockheed had made 693 employment offers at Kennedy Space Center and received 672 acceptances. At Vandenberg there have been 132 offers with 108 acceptances. Of significance is the "capture rate" of personnel actively sought by Lockheed due to their individual capabilities. This stands (as of early December) at 99% for employees of Boeing Services International, Computer Science Corp., and RCA Service Company; 84% for Martin Marietta Corp.; and 97% for Planning Research Corporation. It is important that this success rate be maintained among contractors whose final transition dates occur after February 1984. Lockheed estimates that total personnel at Kennedy Space Center will be reduced by about 1030 at the conclusion of the transition period from the nearly 5800 persons initially available. The Aerospace Safety Advisory Panel recognizes that there is a small population of highly critical people who because of their experience and knowledge will be hard to replace, and that Lockheed should acquire them to further assure a successful transition. The Aerospace Safety Advisory Panel will monitor these essential skill areas to determine the degree of success achieved.

A major factor in selection of the Lockheed team was the fully integrated management structure that established clear relationships between the organizational elements of the Shuttle Processing Contractor and the work to be performed. Lines of communication, authority, and responsibility were directly drawn between top management and the organizational elements. Personnel of other team members--particularly Grumman--were (and are) integrated throughout the organization, along with the functional assignment of Vandenberg Air Force Base operations to Morton-Thiokol, Integrated Ground Operations to Grumman, and Program Requirements Analysis to Pan Am.

With the transition period approximately at the half-way point, it is too early to reach any definitive judgment as to the operational effectiveness of the emerging organization. However, it is possible to identify certain features or principles of the Lockheed plan that indicates a recognition of the challenges and problems in both the near and longer-term. For example:

--A recognition, as stressed by the SPC's top management, that maintenance and well-being of the work force is essential to productive and safe operations. High morale among employees and attention to detail must be sustained for the operational life of the space transportation system, no matter how routine and predictable operations become in the later years.

--Creation of an external Safety Advisory Board (modeled in many respects after the ASAP) that will meet at least quarterly to examine all aspects of the SPC's operations from a safety perspective. Direct access to SPC top management is assured. The desirability of direct communication between this new Safety Advisory Board and the Panel was informally discussed in December.

--Recognition of the need for a common logistics system to support operations at both Kennedy Space Center and Vandenberg Air Force Base. SPC management currently views logistics as its most serious and difficult problem. This responsibility is

hampered by NASA's own ambiguity concerning a total logistics, spares, and maintenance program. The SPC has no responsibility for ordering or budgeting spares acquisition. It is also not SPC's responsibility to plan major or minor maintenance "downtime" for Orbiter refurbishment. This must be resolved if the logistics system is to adequately support operations.

--An expressed determination to drive operating decisions to the lowest possible level in order to (1) strengthen responsibility at the hands-on level and (2) take advantage of the expertise and knowledge of those persons actually doing the work. Day-to-Day instructions are not to come from top management.

--Recognition of the lack of commonality among the Orbiters and the related assumption that maintenance and logistics procedures must take these differences into account for the life of the program.

--The decision to work toward zone-type processing of the Orbiter where a particular area is worked completely and closed-out only once, as distinct from the present system of numerous close-outs as individual systems are processed separately. Related to this approach is the objective of assembling all needed instructions and parts in the immediate location or station where the work is to be performed.

--Establishment of direct links between the SPC's planning organizations--Program Requirements Analysis, Mission Management Office, and Software Integration Office--with comparable Level III entities at NASA. These direct communication channels will facilitate technical expertise being readily available and provide channels of information for NASA to observe element performance and share in the decisions to further simplify "turnaround" procedures.

These various organizational arrangements and operating principles will be monitored by the Panel as they are implemented. Nevertheless, they provide evidence at this juncture of a management approach that appreciates the continuing risks and difficulties of Shuttle processing, as well as the opportunities to develop a more efficient and cost-effective operation.

NASA'S Support of the Shuttle Processing Contractor (SPC)

In prior annual reports and in other reports to NASA management, the Panel has emphasized the importance of moving toward an organizational arrangement within NASA that takes account of the special needs of the Shuttle's routine, more nearly commercial type, operation as distinguished from the prior research and development effort. In July 1982 we noted, for example, that a "well-defined and stable organization within NASA to oversee STS operations is the anchor for the SPC." The selection of the SPC and initiation of its responsibilities makes this observation more timely and pertinent than ever.

Last year the Panel suggested that the "organizational arrangement within NASA that is to be responsible for commerical operation of the Shuttle should be determined and announced, even though full implementation of this arrangement might not be feasible for the next several years." The Panel's assessment of the current status of the Shuttle Processing Contractor indicates why this recommendation still merits consideration. For example:

--The interim logistics procedure now in effect essentially continues control of all flight hardware with Johnson Space Center and Marshall Space Flight Center. While this arrangement is appropriate for the immediate period when the SPC is building its capabilities and establishing a confidence level among NASA managers, the time is fast approaching when retention of this control by research and development centers will more than likely

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impede processing operations. Planning should begin now for an orderly transfer of this oversight responsibility within NASA to an STS operations entity.

--A comprehensive maintenance plan for the Orbiter is lacking. NASA's Operations and Maintenance Instructions (OMI's) provide maintenance procedures but not a baseline from which risks can be assessed. Preparation of such a plan would undoubtedly be a priority assignment of an STS operations entity, carried out in collaboration with Johnson Space Center, Marshall Space Flight Center and the new Shuttle Processing Contractor.

--Operational problems of some magnitude can be expected for the SPC once the Vandenberg launch facility is activated. For example, conflicts between NASA and the USAF for priority of spare parts and perhaps ground support equipment will have to be resolved if the SPC is to carry out its processing responsibilities on both coasts. Resolution of these problems will be facilitated by the existence of an STS operations entity within NASA.

--Flight schedules at KSC and VAFB should be established that permit the SPC to deploy its human and material resources in a cost-effective manner.

--The SPC should participate in the review process that leads to major hardware acquisitions and enhancements that relate to Shuttle processing activities.

The Panel is encouraged by the approach and apparent organizational and technical capabilities of the SPC. The preparation for this significant step toward achieving a genuine operational space transportation system has been thorough and sensibly carried out. Both NASA and the Lockheed team, along with the incumbent contractors, have contributed to this generally positive situation. As noted above, however, the Panel will continue to monitor these activities as the SPC assumes its full responsibilities and as the flight rate accelerates.

NASA RESPONSE TO CALENDAR YEAR 1982 REPORT

The 1982 report of the Aerospace Space Safety Advisory Panel to NASA contained many references to the transition now taking place as the Space Transportation System (STS) approaches operational status. It was tne purpose of these 1982 comments to emphasize to NASA the importance of planning and then creating the organization, and inventory necessary to support the proposed increases in rate of STS launches, safely. A concern with any new system, as important and as complex as this STS, is that the need to satisfy potential customers drives a development into changes to improve performance rather than reliability. In addition, design or procedures simplification may have impact on performance but could have major influence on the cost, time for turnaround, and the safety of operations. The general tenor of NASA's response to the ASAP's 1982 report demonstrated the continuing strong bias of NASA management to spend the limited resources on major performance changes and to relegate changes for reliability and safe reduction of turnaround time to a lower priority. The ASAP hopes that this bias will not continue.

The Panel has reviewed the NASA response and has discussed each element of that response in an effort to deduce our own performance and to plan our future efforts to be more effective. In the following, point-by-point review of the NASA response, we offer some measure of self-assessment:

Recommendation 1 - The program for completing all flight test objectives.

NASA has given us a schedule which should complete the determination of aerodynamic performance, loads, etc., by mission 51-B (STS-20). We still feel that this subject deserves high priority and that flight data are necessary before we fully understand the structural and performance capability of the STS.

Recommendation 2 - Maintaining structural factors of safety.

NASA's outline of how future flight test information will be obtained, and its plan for instrumentation appear to be satisfactory. We concur in principle in the exchange of the Flight Acceleration Safety Cutoff System (FASCOS) to replace the Flight Acceleration Monitor Only System (FAMOS) for engine vibration monitoring.

Recommendation 3 - Single responsible operational logistics organization.

NASA's goal as outlined in SFO-PD-110.5, "NSTS Integrated Logistics Support Policy," is commendable and the ASAP concurs with it in principle but we feel that the time to develop, and the lead time to acquire major spares suggests more emphasis is needed from Headquarters. As will be noted elsewhere, the Shuttle Processing Contract alone does not solve the problem, no matter how capably the SPC contractors perform. Scheduled major and minor repair cycles need to be determined and spares ordered. This is not in the SPC work statement.

Recommendation 4 - Sustaining engineering.

The Panel has not succeeded in presenting a convincing case to NASA to separate this function from the engineering cadre that has accomplished the development and is now engaged in the engineering for performance improvement. We still believe it is timely to make this change.

Recommendation 5 - Hardware/Software certification.

The Panel is pleased that the Chief Engineer's Office is addressing this policy. When it is available for evaluation the Panel will meet with the Chief Engineer. The Panel did not make

clear in its recommendation that it was seeking only a policy, not a summary of what was or was not certified.

Recommendation 6 - Autoland demonstration.

The Aerospace Safety Advisory Panel realizes now that it pressed prematurely for the demonstration of this system. It is obvious that the system is not yet acceptable to the astronauts for full dependence and that a real hazard may exist if the pilots are required to take over from a malfunctioning system late in the landing sequence.

Recommendation 7 - New design for the turbomachinery for the SSME.

NASA's three phase program for improvement and redesign of the power head and its turbopumps is a most thorough response to this problem. The ASAP will follow each phase in the expectation that subsequent Space Shuttle Main Engine (SSME) elements will have enough functional margin to justify repeated use at the 109% thrust level now being tested for certification. This subject is also included in the conclusions and recommendations of this 1983 annual report.

Recommendation 8 - Landing gear integrity.

The ASAP is not satisfied with the response to its 1982 suggestion. An expanded discussion of this element of the STS is included in this, the 1983 annual report.

Recommendation 9 - Structural modifications of Orbiter 102.

NASA must certainly maintain as regular a schedule as possible of useful Shuttle launches and the ASAP recognizes why the suggestion to do full structural modifications on Orbiter 102 became impractical. Elsewhere in this report we have noted our

continuing concern for the structural integrity of the Orbiter at its full payload capability and we are following NASA's flight planning to assure ourselves that adequate placards are in place until the structural loads and strength capability have all been defined.

Other Issues

Automatic entry and automatic braking:

The Aerospace Safety Advisory Panel accepts NASA's response that a complete automatic reentry implies many change in ground control concepts and manual inhibit responsibilities for the crew, and the Panel agrees that the likelihood of incapacitation of the entire crew is remote. Such a response does not cover the more detailed suggestion that automatic gear deployment and auto-braking should be considered to provide redundancy at a critical time.

Role of crew vs. ground control:

NASA response indicates progress toward more autonomous crew responsibilities and the ASAP commends such efforts. Separating the various segments of the operation into launch, on orbit and entry is useful in analyzing crew responsibilities and should be continued. The ASAP included one other phase in its discussions and that was the phase of flight readiness prior to launch. It is the Panel's suggestion that some simplification in procedures, some added confidence in on-board instrumentation, and some time saved might be possible if the cockpit were used as a major readiness check station in much the same manner as the cockpit of a complex airliner or combat aircraft is used.

Safety improvements:

The Panel recognizes that a consistency review of the redundancy of all the systems and backup systems on the STS is a monumental undertaking but we all feel that such a review is both possible and profitable because we believe that simplification of present systems may be the result (thrust vector control of solid rocket nozzles may be a good example).

NASA's response which included a review of the 1200 items on the Critical Item List approaches the Panel's concerns in a different but perhaps equally effective way. It is hoped that a critical item review and presentation can be made to the ASAP in 1984.

Noted elsewhere but worthy of repetition is that the Phase I, II, and III improvement programs in the operational suitability and spares determination for the Space Shuttle Main Engine is an example of a well organized approach to safety consistency. The Panel suggests a similar program for other major subsystems of the STS such as the auxiliary power unit.

APPENDICES

1. Safety of Flight Operations
2. Upper Stages
   - Inerital Upper Stage
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7. Listing of Panel Activities for CY 1983
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Appendix 1

SAFETY OF FLIGHT OPERATIONS

Nineteen hundred eighty-three was a significant year in the evolution of the management of flight safety in NASA aircraft operations.

The good aspects were: (1) the revitalization of the Intercenter Aircraft Operations Panel (IAOP), (2) the reorganization in NASA Headquarters that established the Aircraft Management Office (AMO) as the single office for directives and policy leadership for aircraft operations, and (3) the constructive recommendations from ECOsystems International, Inc. which reinforced many of the previously reported findings of the NASA in-house review teams. An organizational entity such as the AMO could improve what appears to be poor communication from the general management level to and from the flight operations level at the Centers.

The IAOP, through its panels and subgroups, met several times culminating in a full panel meeting at NASA Headquarters in the fall of 1983. The Headquarters staff presented a compendium of the recommendations from NASA in-house reviews, accident and incident reports, and reviews by ECOsystems International, Inc. The meeting closed with an admonition from the chairman to get on with the job of correcting any deficiencies in management for which they had responsibility. As a result of the IAOP work, changes in supervisory procedures and practices have been made at the Center level.

Evidence of poor communication with Headquarters can be deduced from some of the recommendations made by in-house and ECOsystems report--recommendations for the correction of situations that local air operations management had obviously

recognized, and had been unable to correct because of lack of support from higher management levels.

The ASAP has followed "example" relationships between the Centers and Headquarters including direct participation in several accident investigations. Center performance, as observed by ASAP was much improved, yet little commendation and much criticism appeared to be the character of comments from Headquarters. A more permanent Headquarters "focus for flight safety" should alleviate this problem.

Appendix 2

UPPER STAGES

Inertial Upper Stage

The first flight of the Inertial Upper Stage (IUS) from the Shuttle failed to put the Tracking and Data Relay Satellite System (TDRSS)-A spaceraft in the planned geosynchronous orbit. At the end of the IUS second burn, the IUS-1/TDRSS-A stack was in an orbit with a perigee some 7500 n.mi. lower than planned and in an uncontrolled tumble at about 30 rpm. The spacecraft was separated as a result of a command from the ground and, by means of the attitude control system thrusters, was stablized and subsequently raised to the desired orbit.

An intensive investigation was conducted and the multiplicity of anomalies were sorted out. Most of the anomalies were the consequence of a major malfunction. This malfunction was the uncommanded second stage solid rocket motor nozzle displacement that occurred at about 83 seconds into the planned 107 second burn. The IUS control system was unable to regain control of the nozzle positioning during the remainder of the burn despite issuing the command for maximum restoring action and achieving maximum actuator electrical current. After the completion of the motor burn, the nozzle responded to command with correct response. This large deflection of the nozzle caused the observed tumbling.

The investigation concluded that the most probable cause of the malfunction was a failure of the motor "Techroll" joint such that the resultant rapid loss of fluid from the "Techroll" seal lead to the collapse of the seal. In such circumstances, the nozzle would be held in a cocked position by the motor chamber pressure load on the collapsed seal. At the completion of the motor burn the chamber pressure load is eliminated and the

restraining forces on nozzle motion are removed. By making the assumption of such a joint failure it was possible to replicate the flight data in a computer simulation giving credence to the hypothesis.

The exact cause or mechanism of the failure is still under investigation. Evidence to date indicates that a mechanical failure of the seal induced by one or more thermal protection system failures is the most probable cause of the control malfunction. As a consequence, an intensive review of the design and quality assurance provisions for this subsystem has been undertaken. In the absence of evidence of a specific fault leading to the malfunction, it has been necessary to implement a number of design changes to cover the spectrum of possibilities that exists. The changes include providing redundant seals for the fill and bleed ports of the "techroll" seal, providing additional insulation to the thermal protection subsystem to increase the design margin at several locations in the joint area. At the same time tests are being conducted on the original design in an attempt to isolate the cause of the failure. It is anticipated that a redesigned and stringently qualified system should become available by mid-1984.

Centaur

A 2-day fact-finding session covering the Centaur was conducted in mid-July at the General Dynamics Convair Division plant in San Diego, California. This session was the Panel's introduction to the Centaur as a part of the Shuttle program. Most of the organizations involved in the Centaur/Shuttle program provided briefings or had representatives present to respond to questions.

The Centaur program was in the midst of the design phase at the time of the visit. The conceptual designs had been adopted and detailed design was well along. The series of formal design

reviews were scheduled to begin in the last quarter of the year. The test program had been outlined and some of the development tests were in process.

The Panel's principal focus was on the safety implications of carrying a cryogenic propellant rocket stage with pressure-stabilized tanks in the Orbiter payload bay. In general, it appears that the program has identified and attacked the issues involved. Much attention has been given to safety considerations in the design process. The subsystems are being designed to satisfy the safety requirements stipulated for payloads by the Shuttle program. In trying to satisfy these requirements, some of which are more demanding than those imposed on the Shuttle itself, some aspects of the fluid and avionic systems of the Centaur became quite complex. A special review was undertaken to determine if some simplification could be achieved without compromising safety of flight. A Panel member attended a meeting on the findings of this activity and found that a thorough job had been done. There was general agreement that the modified system designs were satisfactory but that some waivers of requirements were required. This is occasioned by the fact that for payloads "damage to STS equipment" is categorized as a "catastrophic failure" regardless of the consequences of such damage. As a failure mode that is classified "catastrophic" is not permitted, additional redundancy is required and leads to the overly complex systems encountered. The issue is being pursued through the required channels.

The Centaur/Shuttle program (Headquarters, JSC, LeRC, KSC) provided detailed responses to Panel questions and comments regarding the Centaur flight and fixed elements and their integration into the Space Transportation System. This continuing dialogue between Panel and program personnel provides a sharing of the results of ongoing studies and decisions reached in those areas that are of vital interest to the Panel.

The Panel will continue to monitor the program actively as it progresses. In particular, we plan to attend the several design reviews, test program reviews and program reviews which are scheduled during the coming year.

Appendix 3

PAYLOADS

With the focus of the Shuttle program shifting from development and flight test to operational use, the Panel has increased its emphasis on the review of the payloads to be transported by the Orbiter. Summary observations on a number of the payloads examined follow.

Orbital Refueling Demonstration

The Panel was represented at the first design review meeting and at the Phase I/II safety review meeting for this project. As would be expected, the focus of safety concerns is the presence of hydrazine in the experiment. Of principal concern are: The possibilities of hydrazine leakage, adiabatic detonation, ullage recompression, exposure of the crew to the propellant etc.

Much progress has been made since the first design review meeting. Among the changes since the first meeting is the elimination of all catalytic vents of the hydrazine side of the system. Each potential hazard is being analyzed methodically and the design is being scrutinized in a thorough manner to assure that the system meets all NASA safety criteria. One open issue is how to treat the possibility of an astronaut getting his EVA suit contaminated with hydrazine and assuring it is clean before entering the air-lock.

The system design is progressing well. There is a very good team on the job. Much work remains to be accomplished prior to the scheduled flight date. Continued thoroughness of design and safety review coupled with satisfactory completion of the test program is required to reduce the risks to acceptable levels. The Panel will continue to monitor this project.

Spacelab

The Panel was represented in the Phase III safety meetings which were the final safety reviews for Spacelab I. There appeared to be great depth and thorough analyses of payload safety as indicated by the representatives of the participating centers.

It appears to the Panel that the project has been well managed. The matrix format that was utilized was designed to assure that each item was evaluated for individual hazards and the consequence of each such failure on its system. Further, interface analyses had been conducted to assure that each system does not impact adversely on other systems and on the entire payload. Final approval of the results of the review rested with the STS project.

It is suggested that the Panel be kept informed about schedules and plans for such safety reviews at their inception so that it may begin to observe the process as early as possible. With such early involvement, it would be possible to gain a broader comprehension of the payload project and the issues that arise thus permitting the Panel to render a more informed and, therefore, complete assessment.

Appendix 4

EXTRAVEHICULAR ACTIVITY

Suits and prebreathing

Extravehicular activity (EVA) is increasing as the STS project reaches out with new and more sophisticated programs. All EVA has been conducted to date using a 4.3 psi suit. As far as the Aerospace Safety Advisory Panel is aware, all EVA activities have been routine except for the first flight. The current suit, because of its low operating pressure, requires an extensive period of prebreathing of 100% oxygen (up to 4 hours) prior to attempting an EVA from a 14.7 psia cabin. This precaution is necessary to avoid decompression sickness (bends) of astronauts when going EVA.

On mission 41-B (STS-11) the cabin pressure will be reduced from the normal 14.7 psia to 10.2 psia before initiating EVA to acclimate the astronauts to the lower pressure. This allows prebreathing time be reduced to about 40 minutes as well as decreasing the astronaut's susceptibility to decompression sickness.

For the future, research is being conducted on a higher operating pressure suit at 8+ psi. This new suit design is to have much greater flexibility in the shoulder, arm, and leg joints, than that of the current suit. The new design has the capability of greatly reducing or eliminating prebreathing requirements.

It is the view of Aerospace Safety Advisory Panel that as time progresses there will be an increasing need for the higher pressure more flexible suit. While current NASA plans may not require this new design, we can visualize the increasing need for it as missions become more complex and the Air Force begins to

use the STS for its own missions. The ability to go EVA with little or no prebreathing is a big plus. The greater flexibility of the new design when combined with the proven torso of the existing design should decrease workload of the astronaut and reduce his susceptibility to decompression sickness.

We believe that NASA should foster the full development of the higher pressure suit and when fully tested it should become the standard suit for all future EVA activities.

Manned maneuvering unit

This short range versatile spacecraft, the manned maneuvering unit (MMU), has been conceived for use as a controllable platform which can transport an astronaut on a short radius from the Orbiter payload bay to satellites near the Orbiter or to inspect the external surfaces of the Orbiter itself. The purpose for the transportation of the astronaut is to place a member of the crew in a position to inspect, repair, and help retrieve satellites whose orbits can be reached by the Shuttle. Sufficient control power is designed into the MMU to permit the passenger astronaut to use the thrusters on the MMU for controlling the motion of randomly moving satellites and to tow them back to the Shuttle for repair or return to earth.

The concept of the MMU and its systems, along with the operational plans and developed capabilities, was reviewed by an Aerospace Safety Advisory Panel member at the contractor's plant (Martin-Marietta in Denver, Colorado). In addition, the simulator work, the facility, and the training program were also described and shown. Simulator training was assessed along with methods for coupling the astronaut to the Solar Maximum Mission (SMM) satellite. Similarly, the adapter hardware and procedure for attaching the MMU to the payload bay wall was viewed as part of the total description of how the "space-suited" astronaut

mounted the vehicle, detached it from the payload bay wall and reattached it once the mission was completed.

From this individual but thorough review, the Panel notes:

a. The concepts of redundancy for critical systems are consistent, the systems are simple and sufficiently exposed to permit thorough inspection.

b. The cold gas thrust and attitude control system is susceptible to pre-use inspection prior to disengagement from the Shuttle bay wall.

c. The gauge indicating energy available to the thrusters was in a poor position for visual monitoring while the astronaut was secured in the unit's seat. It seemed feasible to move this gauge without destroying the integrity of the systems tests that have been run.

d. The training program has been developed pragmatically along with the unit and appears to be effective. After the first experimental flight with the MMU this program and the formal documentation should be reviewed again by the Aerospace Safety Advisory Panel.

e. It was determined that no "safety" umbilical (tether) is to be used for the first experimental flights and is not contemplated for ultimate operatioanl use. This appeared to introduce unnecessary risk, but the astronaut trainer-director for the program explained that umbilical tangling and snagging represented a hazard judged to be equally severe and that the thruster system of the MMU did not have enough

capacity, even if stuck in "full thrust", to move the passenger out of range of the Shuttle capability for astronaut rescue. Additionally, the "buddy system" provides that a second astronaut in the regular EVA suit will be there.

Based on discussions at the MMU Critical Design Review held November 1983 an additional comment can be made: If, for any reason, there are significant amounts of dust/debris in the payload bay during ground or flight operations, care should be exercised to prevent MMU pneumatic systems from being contaminated which might adversely affect their operation.

Appendix 5

LOGISTICS, MAINTENANCE, SPARES AND OPERATIONS

This discussion is based on three specific activities: (1) General Abrahamson's meeting at Kennedy Space Center in November 1982, (2) attendance at a logistics telecon at Rockwell International, Downey, California, in April 1983, (3) visit to Vandenberg Air Force Base in October 1983. In addition, major events have occurred during 1983 which have direct bearing upon the subject:

a. Creation of the Integrated Logistics Panel (ILP) and commencement of working liaison with Vandenberg AFB. This is noted in a Program Directive, SSPM No. 85A issued by JSC's NSTS Office, March 25, 1983.

b. Issuance of an Integrated Logistics Support Policy (ILSP) for the National Space Transportation System establishing a platform for (a) above.

c. The award to Lockheed of the Space Shuttle Processing Contract (SPC).

The meeting at Kennedy Space Center convened by Gen. Abrahamson on November 9, 1982 was the catalyst for the more vigorous logistics, maintenance and support activities which have gradually evolved during 1983.

The Integrated Logistics Support Policy is commendably detailed with seven appendices: Management policy, spares policy, maintenance and repair policy, logistics support functions policy, ILS milestones, ILS definitions and ILS top level documentation tree. It would appear that a number of management level people in both NASA and USAF are looking to the establishment of the Lockheed-managed SPC as a partial answer to

many logistics problems but, although the ILSP was produced concurrently with the contractor-selection award process, the directive does not cite an SPC role in this arena. It is too early to be able to gauge the effect of the SPC program upon logistics but clearly it must necessarily be heavily involved, at both KSC and VAFB.

With respect to the scope of the ILP task, there is concern that it does not include logistics for the Spacelab, Centaur, IUS and PAM elements. It certainly appears that only a complete system ILS program, that is, including the vital payload elements, would have the desirable result of ensuring that the vehicle launch dates can be met from the support viewpoint.

The issue raised by the Aerospace Safety Advisory Panel in earlier annual reports, namely, that of providing logistics control by a single entity appears to remain for the future. The cooperation and growing cohesion of the USAF-Vandenberg and the NASA-JSC/KSC elements is very encouraging but the co-chairing arrangements of the ILP, necessary as they may be at present, do not make for efficient operation in trying to recover some of the critical time lost over the past three years.

The task of the ILP is greatly complicated by the necessity of trying to match the USAF well-developed organizational and management systems with the equally well-established "three-level" system at NASA. This results in a number of organizational "wiring diagrams," interface and procedural documents, few of which, at this writing appear to be completed.

While the issues of supply of components at the line replaceable units (LRU) level appear to be documented and understood some of the necessary suppliers may not be funded. Progress is most certainly being made in detail components but major units such as the SSME with its critical sub-assemblies still are in need of a good, clearly established master plan.

There is also the logistics aspects of transporting the SRB segments to VAFB which are in need of reinforcement for which the case for a third set of rail cars is being made.

Storage space at KSC for SRB segments is limited (although VAFB seems to be better off in this respect) and there is clearly a need for a study involving a "transportation model" to resolve some of these issues before they become a trans-continental transport crisis. In this general context the critical dependency upon only one B-747 Shuttle ferry vehicle for coast-to-coast movement should be re-examined.

Based upon our observed development of the logistics spectrum over the past year it appears that:

a. Considerable progress has been made in trying to gain control of the logistics problem. Improvements in NASA's interest and organization for Integrated Logistics System and sincere cooperation and coordination by USAF for the projected VAFB operations are certainly showing results.

b. There still appears to be issues associated with who has the responsibility for Orbiter, that is to say between the USAF and NASA. (The Directive says that the Air Force has responsibility for it "on-orbit." This needs clarification.)

c. The "reporting to" functions of the Integrated Logistics Panel (ILP) are still unclear. Should, for example, the ILP report directly to the National Space Transportation System Program Office? Should the ILP functions also embrace logistics aspects of operation and launch instead of being limited as at present to supply and

support tasks? The charter of the ILP, in spite of well-written directives from NASA Headquarters and Johnson Space Center is still unclear.

d. Considerable worry has been voiced throughout the year about the lack of ILP access to the Spacelab, Centaur, Inerital Upper Stage, and Payload Assist Module systems and the question therefore arises: is the ILP intended only to support Shuttle and not the broad spectrum of NSTS which would include these payloads?

e. The USAF view seems to be that they can't see anything in the NASA system at present which could be recognized as a well-developed maintenance, supply and logistics curriculum such as the USAF have developed and refined over the years. On the other hand, it appears that the evolving NASA logistics programs are more suited to the special problems of the small Orbiter fleet than the highly-structured, large fleet concepts of the USAF. Providing a workable accommodation between these two opposing philosophies would seem to be a pre-requisite for the ILP but it must be empowered by directive to be able to bring about such a foundation.

f. The "co-chairing" of the ILP by USAF and NASA is clearly the only arrangement which could be employed at this stage. Perhaps it is too early to establish the function of an overall "czar" of logistics but the difficulties which are beginning to show up from this rather too democratic co-chairing process could probably be short-circuited by the early appointment of a strong top chief with total authority.

g. The role of the SPC in the entire scheme of things needs to be determined and made visible to all concerned as soon as possible if some of the program's aspirations are to be realized.

Appendix 6

SPACE TRANSPORTATION SYSTEM ELEMENTS

Orbiter Landing Speed and Pitch Control

The Aerospace Safety Advisory Panel has, in the past, called attention to major deficiences in handling qualities of the Orbiter. These deficiencies are well known, highlighted by substantial pitch gyrations during the Approach and Landing Test No. 5 and some subsequent landings. Such control perturbations have been examined by analysis and numerous simulator control explorations. The Aerospace Safety Advisory Panel believes that NASA top management should direct further exploration of the significant benefits to be gained by major changes to improve the pitch control of the Orbiter.

The latest information that the ASAP has found on this problem is a report of the flight control system testing done on the Ames Vertical Motion Simulator (VMS), entitled: "Evaluation of the Space Shuttle Approach and Landing Flight Control System Handling Qualities" by S. D. Griggs, R. J. Grabe, and S. R. Nagel. This study, carefully conducted over a period of several months, by competent engineers and pilots with extensive experience in high performance airplanes and Shuttle simulations, resulted in the following recommendations:

a. Do not replace the current Flight Control System with any of the alternate systems evaluated. Some were found to be slightly better, but not to the extent that a change to the baseline system is warranted.

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b. Investigate the feasibility of improving the low speed handling qualities of the Orbiter through airframe modifications, such as the addition of canard surfaces.

Eight different flight control systems were evaluated including software modifications to filters, gains, feedback paths, senor, etc. Ten pilots flew approaches to runways simulating Dakar, Kennedy Space Center, and Edwards Air Force Base. Disturbances were introduced during the approaches to stimulate transients in sensor data, such as changes in radar altitude, in azimuth from the microwave landing system, head/tail winds, and reduced visibility return as in a breakout from low cloud deck. The Heads Up Display (HUD) was not used.

The results show substantial variations in touchdown point, airspeed at touchdown, and vertical speed at touchdown ($\dot{h}$). Different software "improvements" failed to show significant changes; -- and there were a number of "crashes". A "crash" is defined as landing short or long or left or right or with $\dot{h}$ greater than 10 fps.

Pilot comments on the baseline system were:

> "Easy to balloon under stress"
> "If aircraft disturbed, end up hunting for ground"
> "Cannot control aircraft precisely near ground"
> "Lag between rotational hand controller (RHC) and vehicle response causes over control for large inputs and undercontrol for small inputs."

These comments on the performance of the recommended system indicate that there is a basic pitch control problem in the aerodynamic design of the Orbiter.

It appears that the attempt to combine pitch and roll control with lift augmentation by the use of elevons on a delta wing

results in compromises that have penalized both pitch control and lift augmentation.

The pitch control problem arises from the fact that, on the landing flare, to reduce airspeed, the pitch up moment is accomplished on the Orbiter by raising the elevons which inherently decreases lift coefficient with loss of lift, increasing the landing speed. The loss of lift is in response to a control motion that a pilot normally uses to raise the nose and increase lift! In addition, the inertia of the Orbiter is such that the motion of the c.g. lags the control input by as much as two seconds. The lag and apparent lift reversal can induce over control, and, in some cases, severe pilot induced oscillation (PIO).

The use of canard surfaces to provide pitch control would free the elevons to be used for lift augmentation and roll control. The elevons would have to be limited in droop to maintain adequate roll power but in spite of this, the available increase in lift would be most significant. Estimating from a nominal landing speed of 175 knots, angle of attack of 10^{o}, elevon angle of 0_{o}, produces an apparent lift coefficient of 0.41. Using the elevons as landing flaps with a canard trimmer might produce double this lift coefficient with a possible landing speed of 125 knots.

The above increase in lift coefficient is not impractical. The advantages of such a landing velocity reduction are very significant from a safety viewpoint:

a. Stresses on wheels and brakes are reduced
b. The risks of landing at Dakar or other short fields are reduced, opening up many alternate abort sites
c. In the event of ditching in the open sea, the probability of survival would be greatly enhanced.

One of the significant findings in the Ames Vertical Motion simulator tests was an appreciation of the dangers of attempting a high-weight low-speed landing (like an abort to Dakar). If the angle of attack is increased much above 10°, in an attempt to land slowly, the aerodynamic condition is one of "backside of the L/D curve" where the induced drag rapidly decelerates the Orbiter and increases the sink speed.

In addition to the safety aspects of low landing speeds, the avoidance of pilot induced oscillation must be emphasized. To the non-pilot, the term "pilot induced oscillation" is just that: a disturbance that is felt to be controllable and transient. To the pilots who have experienced it, including the astronauts, it is recognized as a potentially uncontrollable instability. The lack of a landing incident to date is a tribute to the skills of the astronauts, and to the carefully planned and executed training program in high performance aircraft, the Shuttle Training Aircraft, and simulators.

Space Shuttle Main Engine

The current year began unauspiciously for the Space Shuttle Main Engine (SSME) with the discovery of leaks in the STS-6 engines and the resultant delays in scheduled flights. There were a number of intensive reviews of the problems and their systems and management implications. Panel members participated in several of these reviews. Corrective actions were devised and implemented. Subsequently, the engines performed essentially as predicted in all the flights this year. During the STS-8 flight an Augmented Spark Igniter line failed during the shutdown sequence. This had no effect on the mission. The cause of this failure has been identified and corrective action implemented.

Because of the very limited life (one or two flights) demonstrated by the turbomachinery during the FPL (109%) certification test program and in the absence of near-term

flights requiring that thrust level, it was decided to limit planned flights to 104% thrust. Such "derating" is a prudent step. Not only does it provide added operating margin for the SSME, it also should result in longer useable life for the turbomachinery. This should mitigate the logistical problems that would be caused by the need for frequent change-out of turbopumps that are operated at 109%.

The SSME project has embarked on a three-phase program to achieve a long-lived, reliable full power load (FPL) engine. The first phase involves conducting certification extension tests at 104% to obtain more data on durability at that thrust level. The second phase comprises the orderly development, certification and incorporation of a set of design-detail modifications aimed at solving some of the problems encountered with the current FPL design. The third phase includes major redesign changes. Among them are: Redesign of the Hot Gas Manifold to eliminate non-uniform flows and accompanying parasitic pressure losses; elimination of injector baffles and shields, and increasing the throat diameter of the nozzle. All of these changes will tend to "unload" the turbomachinery thus providing greater operating margins and, hopefully, extended useful life. Also included in the plan are steps to provide new turbopump designs should the preceding not prove effective.

The Panel supports this organized approach to solving the problems of the SSME. Such a program is necessary to provide a reliable engine for higher-power operation and to reduce the logistic burden of frequent component removals.

The Panel would like to emphasize that it is important to set the objectives of this improvement program in terms of demonstrated margins of stresses, temperatures, loads, etc., rather than primarily in terms of time at a given thrust level. Stipulating margins gives recognition to the fact that time-to-failure curves are extremely sensitive to stress,

temperature, etc., in the vicinity of the ultimate stress limits of materials. This is especially true when materials are operated at the high temperatures that prevail in the SSME.

Having demonstrated such improved margins by, among other things, operating the engine at thrust levels above 109% it is of utmost importance to not fall into the trap of considering the engine to be "rated" for operation at the higher thrust level. What has been accomplished is to have demonstrated that there is a margin for operation at 109%. To operate at the highest level tested would be, in essence, to operate without margin.

The Panel will continue to monitor the progress in the program during the coming year.

Orbiter Structural Integrity

The Orbiter structure was designed to loads that have acquired the name "ASKA 5.1." A later set of loads (now called "ASKA 5.4"), based on revised aerodynamic and thermodynamic data, was used for the most current structural assessment. Flight data analyzed to date (strain gage readings recorded on flights STS-1 through STS-5) have not shown reasonable agreement with predicted strain for the same locations using ASKA 5.4 loads. Even though these initial flights were designed to be as benign as possible, the ASKA 5.4 predicted limit strain on the wing alone was exceeded in:

a. 63 instances during ascent
b. 41 instances during descent

Fortunately, there were no instances where the measured strain exceeded a safe allowable limit strain. The numerous exceedances of ASKA 5.4 predicted limit strains without exceeding safe limit strains could be due to:

a. the ASKA 5.1 loads that were used for design were more severe than the ASKA 5.4 used for assessment in the areas where exceedances were measured

b. larger than minimum margins of safety were accepted and used in the design.

Since flight development was officially concluded with STS-5, the development flight instrumentation installed in OV-102 has essentially been dismantled. There does not seem to be an adequate plan to acquire the in-flight data required to close out the discrepancies between flight and analysis data. Therefore, the following steps should be taken:

a. Vehicle OV-102, which was the most densely instrumented vehicle, should have all DFI (Development Flight Instrumentation) gages reactivated and duplicated on both sides of the vehicle and should have adequate pressure measurements added in order to establish a more complete data base.

b. The initial flights were designed to be as benign as possible. With the flight envelope being expanded with each flight, instrumentation should be required on all vehicles in order to safely monitor future flights.

The failure of flight data to validate the current best predictions of structural loads raises serious questions about how the full strength of the Orbiter vehicles can be safely exploited. The Panel views the present situation as follows:

a. ASKA 5.4 loads apparently do not have the correct distribution of aerodynamic forces in the ascent configuration.

b. Current analytical prediction of internal loads and identification of the most critical elements for structural failures are not valid.

c. OV-103, OV-104 and OV-105 wing structure will be more critical than earlier vehicles because of the 800 pounds of structural weight removed in a weight reduction program. The reduction was based on adhering to close margins on ASKA 5.4 loads which, in some areas, were less than the ASKA 5.1 loads used for the original design. Thus, the failure to validate the ASKA 5.4 loads has particular significance for these later vehicles.

d. Future plans include missions that can experience 11% more dynamic pressure (Q) on ascent and 60% higher heating rate on descent than has occurred on STS-1 through STS-5. The best way to prepare to safely fly the most severe mission should be addressed.

Vehicle 6.0 Loads/Stress Analysis

Since the time that the ASKA 5.4 loads were derived (in 1976/1977), both flight and wind tunnel data have been developed that should provide a better basis for generating loads that more closely represent those being experienced by the full-scale flight vehicles. It has been proposed that a new set of loads be derived and used with an updated finite element model to provide a basis for establishing safe structural limits for future flights. This proposed effort has been called the 6.0 Vehicle Loads/Stress Analysis.

The vehicle 6.0 loads/stress analysis would consist of a complete update of the dynamic, thermal and mechanical loads math models that takes into consideration all structural configuration

changes resulting from the OV-103 weight saving efforts and other Shuttle element (ET and SRB) modifications. The followng should also be re-evaluated: aeroheating and thermal gradients, aerodynamic and compartment venting pressure loads, weight distributions, inertia loads, ascent trajectories, and the effects of the redesigned landing gear metering pin. These efforts should be coordinated with the latest wind tunnel and flight test data results in order to establish a new internal loads data base for ascent, descent, and landing conditions. These loads would then be used as a basis for a new stress analysis to establish the operational capability of the vehicle.

The Aerospace Safety Advisory Panel believes that another round of loads analysis of the 6.0 type is necessary in order to safely utilize the full potential of the Orbiter structure.

Filament Wound Case (FWC) For Solid Rocket Boosters

Results of a full-scale hydrotest of two segments of the FWC were reported at the Technical Interchange Meeting at Morton Thiokol, Wasatch Division, on November 16-17, 1983. Full-scale test specimens TFS 2 and TFS 3 were pinned together with proper end closures and external tank/solid rocket booster interfaces and successfully completed hydrotesting on October 21. The test results are as follows:

a. The test ran four maximum expected operating pressure (MEOP) cycles to 1050 psi with a final test to 1478 psi without burst.

b. The fiber strength in TFS 3 was demonstrated to 442 KSI.

c. The factors of safety (F.S) were shown to be:

1.50 Factor of Safety in the membrane for TPS 3
1.42 Factor of Safety in the membrane for TPS 2
1.32 Joint Factor of Safety for All Joints

d. The test specimens show no signs of delamination or wear.

e. All test objectives were met.

Two more full-scale specimens are scheduled to be hydrotested to 140% of maximum expected operating pressure by the middle of January 1984. These tests if as successful as the tests of TPS 2/3, will provide adequate certification of the FWC structural design.

Lightweight External Tank

In last year's annual report the Aerospace Safety Advisory Panel recommended that a nonlinear buckling analysis be performed on the Lightweight External Tank (LWT) structure in the area of the LH_2 tank where maximum compressive stresses are produced by thrust from the Orbiter. This analysis has now been completed by Martin-Michoud, and the method and assumptions have been reviewed and approved by an independent consultant, Mr. David Bushnell, of Lockheed Missiles and Space Company. The results show the LWT to have a 60% margin of safety in compression above the design ultimate load. This will add to the 26.5% margin of safety between the design ultimate load and the design limit load. With these analytical results in mind, the Panel is satisfied the LWT is structurally stable for 109% of SSM rated power level.

Landing Gear Design

For many years the ASAP has been pointing out the inconsistency of the landing gear design loads where the Orbiter has departed from commercial design practice. Normal commercial transport aircraft have built-in margins for the maximum loads expected in landing and braked roll-out conditions since the critical loads are normally refused take-off with braking and a 1/2g turn. Thus comparison with transports show:

	DC-9	L-1011	Orbiter
Max design load equals max stress (% max stress)	100%	100%	--
Braked roll-out (% max stress)	73%	58%	100%
Touchdown at 10ft/sec (% max stress)	71%	34%	--
5ft/sec (% max stress)	--	--	100%
Static load (% max stress)	48.4%	21%	38.7%
Tire deflection (max Ldg Load)	33%	--	66%

In spite of the fact that brake energy (design) has been based on abort landings at 240,000 lbs. there have been actual or incipient brake failures on almost every landing even though landing weights have not yet approached the design maximum valve. A review of the brake energy utilized through STS-5 shows that the pilots have been demanding ever increasing energy. STS-5 used an average of 35.54 millions of foot pounds with a maximum on one wheel of 42.62 millions of foot pounds. This value compares to the maximum energy for emergency use of 55 million foot-pounds and a fuse setting of 42 million foot-pounds, illustrating the marginal capacity of the brakes.

It has been noted by Robert Rothi that the brake pedals require a 75 # force to achieve maximum brake pressure of 1500 psi. This apparently is extremely difficult for the pilot to do consistently because of the long, tiring mission and not applying full force lengthens the stopping distance appreciably. Here is a PRIME situation to incorporate an "autobrake" system. Autobrakes are currently in production use on the 747, DC-10, DC-9, and other airplanes and the systems have been well-developed. Adaptation for use on the Shuttle should be a simple process and would relieve crew workload and result in shorter, consistent stopping distances.

The brakes were initially designed for 3000 psi, but the torque from the carbon-carbon rubbing surfaces peaked so high near the end of the stop on dynamometer tests that B. F. Goodrich, the brake supplier, was afraid of structurally failing the stators and rotors. Hence, the addition of reducers and the reduction of maximum brake pressure to 1500 psi to limit the peak torque.

Repeating again some of the Aerospace Safety Advisory Panel recommendations, it is suggested that NASA:

a. Seriously study the use of a longer nose gear strut or the installation of an expanding nose gear strut to relieve the roll-out loads in landing,

b. Similarly study the feasibility of a 4-wheel truck main gear.

Short of such a major change there are a number of less extensive improvements that NASA should seriously address including:

a. Place the Shuttle main gear tires on a flat surface on individual load cells at the end of a mission

and record variation in load distribution across the Shuttle. It appears that structural deflections on landing must tilt the shock struts outward loading up the inboard tires to higher loads and causing those brakes to absorb more than their proper share of the energies.

b. Move the main tire centerline inward toward the shock strut about one inch and increase the tire size as much as the diametral clearances will allow, maybe H46x17-22, or bigger, with a 5^{o} bead seat.

c. With the larger tire and internal wheel space redesign the brake for greater energy and torque capacity using structural carbon. Support the brake on the axle near the inboard bearing to minimize axle bending.

APPENDIX 7

PANEL ACTIVITIES FOR CY 1983

As in previous years, Panel fact-finding sessions have been conducted on the average of four times per month for 1983. Members and consultants have during this same period visited seven NASA centers and facilities (Ames Research Center, Dryden Flight Research Center, Langley Research Center, Lewis Research Center, Johnson Space Center, Marshall Space Flight Center, Kennedy Space Center) as well as NASA Headquarters, and numerous NASA contractors. Although these have been focused on the Space Transportation System, there have been a number of fact-finding visits aimed at reviewing and assessing aeronautical operations and attendant flight safety. The Panel has, where practical, participated in a number of significant in-house reviews; e.g., Flight Readiness Reviews, various project hardware/software technical meetings, STS Support Activities. Panel efforts have been supported by the Panel Staff Director through in-depth and continuous participation and reviewing of STS and other program/project activities as well as aeronautical R&D and administrative flight safety activities.

The breadth of Panel personal discussions goes from the NASA Administrator and Deputy Administrator to Program Directors on into the subsystem design and test personnel (the "hands-on" people). Beyond this is the Panel's annual report provided to the NASA Administrator, informal meetings with Congressional staffs, and testimony before the appropriate House and Senate subcommittees in January-March period. Where requested, the Panel provides individual support to special review teams such as those looking at the Filament Wound Case for the Solid Rocket Motor, Centaur/Shuttle Safety, and the Shuttle Main Engine Assessment Group.

APPENDIX 7 CONTINUED

SUBJECT: Panel Fact-Finding Sessions Calendar year 1983

Date	Location	Attendance/Subject
1/28-29/83	KSC	STS-6 Flight Readiness Firing (Elverum/Grier)
2/4/83	Rocketdyne Div.	STS-6 Flight Readiness Firing (Elverum/Grier)
2/8/83	NASA HQ	Annual Meeting, 1982 Activities (Panel)
2/22/83	Hercules Corp.	SRM Filament Wound Case (Hedrick/Rothi)
3/2/83	Congress, DC	Panel Testimony to House of Representatives
3/3/83	KSC	STS-6 Flight Readiness Review (Battin/Grier)
3/16-17/83	KSC	Launch Processing Software/Hardware (Battin)
3/30/83	JSC	STS Program Management/Mission Ops (Hawkins/Grier)
4/4-8/83	JSC	Mission ops, aircraft safety, logistics for STS, Logistics Panel, Space Medicine (Parmet/Davis)
4/6/83	Rockwell, CA	Integrated Logistics Panel, Orbiter (McDonald)
4/14-15/83	General Dynamcis	Shuttle/Centaur Level II Reviews (Hawkins/Grier)
4/19-20/83	MSFC	STS Projects (SSME, ET, SRB), Spacelab, Space Telescope, Filament Wound Case (Panel)

4/21/83	NASA HQ	STS Logistics Programs/Policy (McDonald)
4/27-30/83	Rockwell, CA	Space Shuttle Main Engine/Orbiter (Himmel)
5/25-26/83	NASA HQ	TDRSS Ops, Orbital Communications (Battin/Davis)
5/31-6/1/83	JSC	STS Autoland, Flight Trajectories (Battin)
6/1-2/83	JSC	STS Autoland, RTLS abort, Crew Support (Davis)
6/2-3/83	JSC	Spacelab Safety Review (Parmet)
6/8-9/83	Hercules Corp	Filament Wound Case Status/Problems (Hedrick/Rothi)
6/10/83	NASA HQ	STS-7 Flight Readiness Review (Himmel)
6/14-16/83	KSC	Special SSME Management Review Team (Himmel)
6/27-30/83	ARC	Aviation Safety Inspection Review Autoland Simulator operation (Davis)
7/12-13/83	General Dynamics	STS/Centaur Integration and Ops (Panel)
7/14/83	Rocketdyne Div	Space Shuttle Main Engine (Elverum/Himmel)
7/25-28/83	LaRC	Aircraft operational safety (Davis)
8/11-14/83	JSC	Orbital Refueling Test Program (Parmet)
8/23-24/83	MSFC	Technical Interchange Meeting, FWC (Hedrick)
9/14/83	Martin Marietta,	Manned Maneuvering Unit (Hawkins)

9/13-15/83	NASA HQ	Intercenter Aircraft Operations Panel and NASA Aircraft Operations (Parmet/Davis)
9/28-30/83	KSC	Launch Preparations, Shuttle Processing Contractor transition, Aircraft Ops (Panel)
10/7/83	JSC	STS-1 to -8 Biomedical Symposium (Parmet)
10/18-19/83	JSC	Shuttle/Centaur Fluid Systems Safety Review RTG power supply cooling/control (Elverum)
10/19-20/83	MSFC	Filament Wound Case Technical Interchange Review/Meeting (Rothi)
10/19-20/83	VAFB	Integrated Logistics Panel for STS (McDonald)
10/18/83	Congress, DC	Informal meetings with Senate Staff (Hawkins/Grier)
11/8-10/83	JSC	Manned Maneuvering Unit Critical Design Review Orbiter Brakes, Crew Operations (Rothi/Davis)
11/10/83	MSFC	SSME, ET, SRB Production Quality Readiness Review with contractors/government (Grier)
11/16/83	JSC	Orbital Refueling System Safety Review (Parmet)
11/18/83	Brooks AFB, TX	EVA medical status and testing (Parmet)
11/18/83	NASA HQ	STS-9 Flight Readiness Review (Himmel)

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11/30/83	Rocketdyne, Div	SSME 109% Rated Power Level Status (Hawkins/Grier)
12/2/83	KSC	Shuttle Processing Contractor's Status (Stewart)
12/6/83	NASA HQ	Orbital Maneuvering Vehicle, Transfer Orbit Stage, Tethered Satellite and its operations, Inertial Upper Stage status, activities review (Panel)
12/13/83	Nat'l Res Council	Filament Wound Case Special Committee Meeting (Roth)
12/16/83	LeRC	Centaur Critical Design Review (Himmel)

Appendix 8

PLANS FOR 1984

Panel Membership

A number of Panel membership changes are taking place at this time occasioned by events in late 1983. As noted in the front of this report, Robert D. Rothi's passing requires the selection of a new member. Lt. General Leighton I. Davis completed his membership term and has been retained as a consultant to the Aerospace Safety Advisory Panel. Bob Rothi had taken General Davis' position on the Panel. As a result of the selection of the contractor team which included Lockheed and Grumman to perform Space Shuttle Launch and Landing processing at Kennedy Space Center and Vandenberg Air Force Base both Willis M. Hawkins and Ira Grant Hedrick have retired from the Panel. They are remaining with the Panel in a phase-over period to accomplish a smooth transition to new members recently appointed in their stead.

Mr. John C. Brizendine former President of the Douglas Aircraft Company, now an aerospace consultant, has been selected to succeed Willis Hawkins as the new Chairman of the Aerospace Safety Advisory Panel. A brief resume follows:

> John Brizendine completed 33 years with the Douglas Aircraft Company in May 1983 after trying his hand at teaching at the University of Kansas after college graduation. His career included flight test work on a series of high performance research and development, military and commercial aircraft. This culminated in his promotion to Executive Vice President and then President of Douglas Aircraft Company in 1973. John served in the Navy as a Naval Aviator with single and mulit-engine ratings.

Mr. Charles J. Donlan has been selected to fill the vacancy left by Grant Hedrick. A brief resume follows:

> Charles Donlan had 37 years experience in research and development activities with NASA and its predecessor NACA before retiring in 1976. Most of this time was spent at Langley Research Center with the last 8 years spent at NASA Headquarters. Since leaving NASA he has been a consultant to the Institute for Defense Analysis with emphasis on assessing and making recommendations to the DoD on the development of facilities for the space Shuttle operations. His NASA/NACA experience included high speed research aircraft programs and direct involvement with all aspects of manned space flight since the beginning of such programs.

The selection of a candidate to fill the remaining membership position will be made in the very near future.

Panel Activities in 1984

Plans are to continue to focus on a number of aspects of the Space Transportation System as it approaches full operational status, assess the safety implications of upper stages and payloads that interface with the STS and to monitor the safety procedures and practices of NASA's aircraft operations.

Efforts will include at least the following areas of interest and concern:

- Shuttle Processing Contractor progress
- STS logistics and associated operational implementation

- Orbiter
- SSME
- Solid Rocket Boosters
- External Tank
- Launch Processing System at KSC and VAFB

o Vandenberg Air Force Base operations and relationships with KSC

o Upper stages including the Inertial Upper Stage, Centaur, Transfer Orbit Stage, Orbital Maneuvering System

o Filament Wound Case for the STS Solid Rocket Motor

o Payloads and on-board experiments and their integration into the STS, for example:

- Refueling Experiment
- Spacelab
- Tethered Satellite System
- Galileo
- Space Telescope

o Extravehicular Activity (EVA) and its support systems including suits, manned maneuvering systems and life sciences

o Rendezvous and proximity operations in space

o The Solar Maximum Mission spacecraft repair flight

o Space Station

- Certification policy and its implementation including product quality and design suitability, as well as, use of analyses versus tests

- Operational procedures to promote safety in the STS, space station and other programs

- Safety of NASA aircraft operations

AEROSPACE SAFETY ADVISORY PANEL

CHAIRMAN

Mr. Willis M. Hawkins (Retiring Chairman)
Senior Advisor Lockheed Aircraft Corporation

Mr. John C. Brizendine (Incoming Chairman)
Formerly President, Douglas Aircraft Company

MEMBERS

Dr. Richard H. Battin
Associate Department Head
Charles Stark Draper Lab. Inc.

Mr. Charles J. Donlan
Formerly, Deputy Associate Adminstrator for
Manned Space Flight NASA

Mr. Gerard W. Elverum, Jr.
Vice President-General Manager
TRW Space and Technology Group

Mr. Herbert E. Grier
Formerly, Senior Vice President
EG&G Inc.

Mr. Ira Grant Hedrick (Retiring Member)
Presidential Assistant for Corporate Technolgy
Grumman Aerospace Corporation

Mr. John F. McDonald
Formerly, Vice President-Technical
TigerAir, Inc.

Mr. Norman R. Parmet
Formerly, Vice President
Trans World Airlines

Mr. Robert D. Rothi (deceased)
Formerly, Chief Design Engineer
Douglas Aircraft Company

Mr. John G. Stewart
Assistant General Manager
Tennessee Valley Authority

CONSULTANTS

Lt. Gen. Leighton I. Davis
USAF (Ret.)

Dr. Seymour C. Himmel
Formerly, Associate Director,
Lewis Research Center

EX-OFFICIO MEMBER

Dr. Milton A. Silveria
NASA Chief Engineer
NASA Headquarters

STAFF

Mr. Gilbert L. Roth
Staff Director, Aerospace Safety Advisory Panel

Ms. Susan Webster
Advisory Committee Assistant

ACRONYMS AND ABBREVIATIONS

AMO	Aircraft Management Office
ASAP	Aerospace Safety Advisory Panel
ASKA	Automatic Systems for Kinematic Analysis
DFI	Development Flight Instrumentation
EVA	Extravehicular Activity
FASCOS	Flight Acceleration Safety Cutoff System
FAMOS	Flight Acceleration Monitor Only System
FRR	Flight Readiness Reviews
FPL	Full Power Level
HUD	Heads Up Display
ILP	Integrated Logistics Panel
IAOP	Intercenter Aircraft Operations Panel
IUS	Inertial Upper Stage
ILS	Integrated Logistics Support
JSC	Johnson Space Center
KSC	Kennedy Space Center
LPS	Launch Processing System
LWT	Light Weight Tank
LRU	Line Replaceable Units
LaRC	Langley Research Center
LeRC	Lewis Research Center
MSFC	Marshall Space Flight Center
MMU	Manned Maneuvering Unit
NACA	National Advisory Committee on Aeronautics
NASA	National Aeronautics and Space Administration
NSTS	National Space Transportation System
OMI	Operations and Maintenance Instructions
OV	Orbiter Vehicle
PAM	Payload Assist Module
PIO	Pilot Induced Oscillation
RPL	Rated Power Level

RHC	Rotational Hand Controller
SMM	Solar Maximum Mission
SPC	Shuttle Processing Contract(or)
SRM	Solid Rocket Motor
SSME	Shuttle System Main Engine
STS	Space Transportation System
TDRSS	Tracking Data Relay Satelite System
USAF	United States Air Force
VAFB	Vandenberg Air Force Base
VMS	Vertical Motion Simulator

APPENDIX 4

University of Hawaii at Manoa

Institute for Astronomy
2680 Woodlawn Drive • Honolulu, Hawaii 96822
Telex: 723-8459 • UHAST HR

February 23, 1984

Honorable Harold L. Volkmer
Chairman, Subcommittee on Space
. Science and Application
1007 Longworth House Office Building
Washington, DC 20510

Dear Mr. Volkmer:

Thank you for the invitation to present written testimony on behalf of the NASA Solar System Exploration Committee on the NASA FY 85 authorization bill. Enclosed is a statement which I hope will be satisfactory. If there is anything further I can do to be of assistance, please let me know.

Sincerely,

David Morrison

DM:dr

Enclosure

Testimony for the House Subcommittee on Space Science and Applications

Dear Mr. Chairman:

Thank you for the opportunity to comment on the FY 85 NASA Authorization in Space Science. I am David Morrison, Professor of Astronomy and Acting Vice-Chancellor for Research at the University of Hawaii. I am providing this testimony as Chairman of the NASA Solar System Exploration Committee (SSEC), a subcommittee of the NASA Advisory Council. The SSEC was formed by the NASA Administrator in 1980, charged with the task of developing a mission plan for planetary exploration through the year 2000. The first part of the SSEC report, dealing with a Core Mission Plan, was issued in 1983 and has been accepted by the Agency. The second part of our report, dealing with missions that will require an augmented NASA planetary budget, is in preparation and will be published later this year.

Since the FY 85 NASA budget raises no issues concerning an augmented planetary program, I will limit my comments to the SSEC Core Program. The SSEC feels strongly that it is important for the U.S. to undertake some larger, more challenging planetary missions in the future, but at present our first priority must be to re-create a viable base by implementing the Core Program, which represents the minimum planetary program in a financially restrained environment.

The SSEC Core Program recommendations include four major issues that involve the FY 85 budget authorization. These issues are summarized as

follows:

- Venus Radar Mapper (VRM). This is the first of the new, lower-cost planetary missions recommended by the SSEC. We are pleased by the progress being made with this mission, which was an FY 84 New Start, and we fully endorse the NASA budget request for continued development of VRM, leading to a 1988 launch.

- Planetary Observers. A central element of the SSEC Core Program is the initiation of a continuing series of low-cost Observer missions based on modified Earth-orbital commercial spacecraft. The first of these Observer missions is the Mars Geoscience/Climatology Orbiter (MGCO), and we are pleased to support the NASA request for authorization to proceed with an FY 85 New Start for MGCO. We are concerned, however, that the Administration request does not specifically acknowledge that this is the first of a continuing Observer line item. Many of the cost savings identified by the SSEC can only be achieved in subsequent Observer missions by block buys and other management approaches based on a continuing mission set, similar to the Explorers in the Physics and Astronomy program. The SSEC strongly urges that the Observer line, as well as the MGCO, be authorized. This action will not affect the FY 85 or FY 86 budget figures, but it will permit significant savings later as the second and third Observer missions are initiated.

- Mariner Mark II. This new generation of spacecraft is being

designed at JPL for missions to the outer planets and to comets and asteroids. The SSEC is pleased with progress being made in this area, and supports the current level of support through Advanced Technology Development funds.

- Planetary Research and Analysis. The SSEC has recognized the importance of supporting research and analysis of data from past missions in maintaining a viable base program of planetary science and exploration. This area has been especially hard hit in recent budgets, although Congressional appropriations above the level of NASA requests has done a great deal to keep this program vital. Unfortunately, the current NASA FY 85 request again cuts the Research and Analysis budget, and if adopted it would provide a shortfall of approximately $10M from current levels. It is essential for the survival of a viable research program that this $10M cut be restored. Further, we note that an additional R&A increase of $5M is required to return this program to its FY 81 level, which is the stated goal of both NASA and the SSEC.

In summary, the SSEC is generally pleased with the progress being made in implementing the Core Program, although we note that the planetary program is still suffering from the severe cuts of a few years ago, and it has not yet recovered to the minimum equilibrium funding level identified by the SSEC. In two areas, however, we find the FY 85 NASA budget request to be inadequate. First is the failure to identify MGCO explicitly as the first of a continuing line of Planetary Observers, an omission that can have a negative impact in future years on the cost-effective development of these missions. Second is the totally unjustifiable cut proposed in planetary Research and Analysis, which requires an addition of $10M to $15M to maintain adequate levels of activity for support of present and future missions.

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